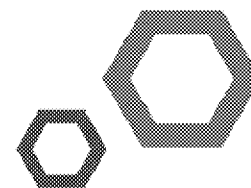


2nd Edition



Global Biopesticides:

An Overview of Natural and Microbial Pesticides in the United States

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GLOBAL BIOPESTICIDES: An Overview of Natural and Microbial Pesticides in the United States

*This report and the survey on which it is based
are the work of and under the direction of:*

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FOREWORD

Global Biopesticides: An Analysis of the Natural and Microbial Pesticides in the United States is the second edition of Kline & Company's study of selected country/crop markets for this market. The study quantifies and analyzes the current use of natural and microbial pesticides across 11 market segments.

The report is based on in-depth interviews with experts in each of the countries examined. The crops analyzed in each country were selected based on our interviews and reflect the crops most often affected by nematodes.

For more focused analyses, Kline & Company can also provide assistance through our custom, strategic consulting capabilities. Having served the pest control chemicals industry since the 1960s, Kline & Company has undertaken numerous consulting assignments to assist clients with development of new products and markets, detailed growth models, and end-user attitudinal research. In addition to these analyses, Kline & Company has completed various other engagements for our industry-leading clients, including:

- Acquisition screening and assessments
- New business development
- Industry/category/brand assessments
- Competitive intelligence
- Strategic analyses

We invite all subscribers to notify us of any errors so that we may correct them in future editions of this survey.

In closing, we wish to acknowledge the efforts of Jim Walter and Ben Kirk in completing this report.

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UNITED STATES

INTRODUCTION

SUMMARY

In this report, the U.S. market for biopesticides includes material that has pesticidal properties and excludes related material that provides nutrients, but does not aid in controlling insects, diseases, or weeds. It therefore includes the following:

- Microbial pesticides, such as bacteria, fungi, virus, and protozoans which kill one or a few species
- Biochemical pesticides are natural occurring substances, such as plant extracts, fermentation products, pheromones, and minerals that control pests by non-toxic mechanisms or are considered organic.

SALES BY CROP/NONCROP SEGMENT

The U.S. biopesticides market is estimated at \$773.0 million at the grower/end-user level. It includes crop and non-crop end-use segments. Field crops is the leading segment in end-user value, with \$236.9 million in sales, or 30.7% of the total. The consumer sector is the second-leading segment in end-user sales with \$217.7 million, or 28.2% of the total, followed by the fruits and nuts segment with \$114.0 million, or 14.8%. The end-user level accounts for the distribution margin required, and in consumer markets that margin is substantially higher than in all the other segments. This margin difference accounts for about one-third of the segment value for the consumer sector.

Vegetables and non-crops account for \$88.4 million and \$68.3 million respectively, or 11.4% and 8.8% respectively, followed by specialty crops with 5.1%. It is interesting to note that the consumer segment sales account for about 5.1% of all consumer pesticide sales. In addition, they comprise about 10% of pesticide sales on vegetables and fruits and nuts.

Table 1: Sales by End-use Segment Included in the U.S. Biopesticides Report, End User Level, 2016

Crop category	Crops included	\$ Million	% Of total
Field crops	Corn, soybeans, cotton (mainly corn)	236.9	30.7
Consumer	Over-the-counter homeowner	217.7	28.2
Fruits and nuts	Apples, grapes, strawberries, other	114.0	14.8
Vegetables	Tomatoes, carrots, leaf lettuce, potatoes, other	88.4	11.4
Non-crop	Turf, forestry, mosquito, pest control, aquatic	68.3	8.8
Specialty crops	Horticulture (nursery/greenhouse)	39.3	5.1
Other	Poultry houses, plant protectants	8.4	0.7
Total		773.0	100.0

PRODUCT SALES

A variety of active substances are used in the biopesticides market. They are defined and explained in detail in the Technical Product Overview chapter of this report.

Table 2: Active Substances Used in the Biopesticide Market in the United States, 2016

Microbes (including bacteria and fungi)	Protazoa
Pheromones	Bacteriophages
Nematodes	Botanicals and plant extracts
Minerals	Fermentation products

SALES BY BIOPESTICIDE CLASSIFICATION

The classification system used for this report is based on generally accepted classification of material being from a natural source and having low toxicity. It generally follows the United States Environmental Protection Agency (EPA) and organic classifications, although it includes minerals such as sulfur and boric acid that do not fall within the EPA's definition but are classified as organic by Organic Materials Review Institute (OMRI). Kline included 25-b products which are technically not registered by the EPA but are sold as insecticides, herbicides, and fungicides. Mammal repellants, which typically are botanical extracts, are also included. The leading class of biopesticides in the United States is microbes, accounting for sales of \$313.0 million, or 40.5% of the total market.

Botanicals account for \$255.9 million, or 33.1%, followed by minerals and fermentation products, with 16.8% and 4.7%, respectively.

Table 3: Biopesticide Sales in the United States by Classification, 2016

Biopesticide classification	Species/types	\$ Million	% Of total
Microbes (including bacteria and fungi)	<i>B. Thuringiensis</i> , <i>B. firmus</i> , <i>B. subtilis</i> , <i>sphaericus</i> , <i>trichoderma</i> , <i>beauvaria</i> , <i>streptomyces</i> , <i>penicillium</i> , <i>verticillium reynoutria</i> , <i>aspergillus flavus</i>	313.0	40.5
Botanicals	Azadirachtin, citric acid, thyme oil, rosemary, cotton seed oil, neem oil, pyrethrins, clove oil, others	255.9	33.1
Minerals	Copper, sulfur, phosphoric acid, hydrogen peroxide, potassium bicarbonate, kaolin clay, others	129.8	16.8
Fermentation products	Harpin protein, streptomycin, oxytetracyclin	36.1	4.7
Pheromone	(E, E)-8,10-Dodecadien-1-ol	17.0	2.2
Viruses	NPV virus for spodoptera, heliothis, codling moth, tussock moth, gypsy moth	4.2	0.5
Nematodes	Steinernema, heterorhabditis, kraussei	4.1	0.5
Others and combinations	N-decanol, pinolene, pyrethrin+sulfur, malaeic hydrazide, others	10.0	1.3
Total		773.0	100.0

SALES BY PRODUCT TYPE

The leading biopesticide product type is bioinsecticides with sales at the end-user level of \$255.8 million, or 33.1% of the total market. The second-leading product type is biofungicides, with sales of \$183.8 million or 23.8%, and bionematicides with sales of \$135.4 million or 17.5%.

Table 4: Biopesticide Sales in the United States at the End User Level by Product Type, 2016

Product type	\$ Million	% Of total
Bioinsecticide	255.8	33.1
Biofungicide	183.8	23.8
Bionematicide	135.4	17.5
PGR	65.7	8.5
Bioherbicide	34.1	4.4
Animal Repellant	22.5	2.9
Molluscicide	17.7	2.3
Bioinsecticide + biofungicides + biomiticide	12.7	1.6
Plant protectant	9.0	1.2
Bioinsecticide + biofungicide	8.9	1.2
Biofungicide + biomiticide	7.3	0.9
Rodenticide	4.0	0.5
All other	13.2	1.7
Total	773.0	100.0

SALES BY ACTIVE SUBSTANCE

Looking at the market by selected active substances with sales of \$5 million or more, Kline finds that 10 materials make up 49% of the biopesticides market in 2016. The leading material is *Bacillus firmus*, Bayer's branded seed treatment, with sales of \$130 million, or 16.8% of the market. A far second is *Bacillus subtilis* with sales of \$64.6 million and 8.4% of the market, followed closely by pyrethrins with sales of \$62.2 million, or 8.1%. *Bacillus thuringiensis* totals \$39.8 million, including *Israelensis*, *kurstaki*, *aizawai*, and ABTS-351. There are many small volume products in the market, and many active ingredients with market share of less than 1% of sales.

Table 5: Biopesticide Sales in the United States by Selected Active Substance with Sales Over \$5 Million, End User Level, 2016

Active substance	Example brands	\$ Million	% Of total
<i>Bacillus firmus</i>	Votivo	130.0	16.8
<i>Bacillus subtilis</i>	Subtalex, HiStick, Vault, Rhapsody, Serenade	64.6	8.4
Pyrethrin (and combinations)	Evergreen, AquaHalt, Worry Free, Earth-tone, Safer, Ortho (Insect Killers)	62.2	8.1
<i>Bacillus thuringiensis</i> ABTS-351/ <i>Kurstaki</i> /other	Thuricide, Javelin, Crymax, Green Step, Dipel, Biobit, Florbac, Xentari, Agree	24.9	3.2
<i>Azadirachtin</i>	Azera, Azatin, Aza-Direct, BioNeem	22.8	3.0
<i>Bacillus thuringiensis Israelensis</i>	Aquabac, Vectobac, Teknar, Summit, Vectomax, Fourstar	14.9	1.9
Neem oil	Trilogy, Green Light, Garden Safe	16.5	2.1
Iron phosphate	Sluggo, Slug & Snail Bait	16.4	2.1
Copper (includes salts)	Kocide, CUPlus, Copper dust	16.3	2.1
Diatomaceous earth	Safer, Victor, J.T. Eaton (Insect Killers)	11.2	1.5
Phosphoric acid	Fungiphite, Phostrol, Rampart	9.8	1.3
Potassium salts of fatty acids	Insecticidal Soap, Earth-Tone, Ortho	9.5	1.2
<i>Reynoutria sachalinensis</i>	Regalia, Regalia Max, Milsana	9.3	1.2
Gibberilic acid (and combinations)	Pro-Gib, Exelis, Gibpro	9.3	1.2
Trichoderma	SoilGard, Sabrex, Bio Ten, Remedier	7.6	1.0
(E,E)-8, 10-Dodecadien-1-ol	NoMate, CM Plus	6.5	0.8
Polyoxin D	PH-D	5.0	0.7
All other	-	336.2	43.5
Total		773.0	100.0

SALES BY SUPPLIER

The leading supplier of biopesticides as defined in this report is Bayer CropScience, with sales over \$149.1 million or 19.3%. Valent BioSciences is the second-leading supplier with sales of \$89.9 million, followed by BASF with sales of \$52.6 million. Valent has benefited from the merger with MGK and a marketing agreement with Monsanto for the specialty market. Scotts Ortho is the fourth-largest with sales of \$36.0 million and has grown from the acquisition of Green light and Tomcat, and is followed by Bonide another consumer supplier.

Table 6: Biopesticide Sales in the United States by Supplier, End User Level, 2016

Supplier	\$ Million	% Of total	Main biopesticide activity
Bayer	149.1	19.3	<i>Bacillus firmus</i> , other
Valent BioSciences	89.9	11.6	Various <i>Bacillus thuringiensis</i> products, Pyrethrin, azadirachtin
BASF	52.6	6.8	<i>Bacillus subtilis</i> (Vault, Subtilex, Histick), Bt (Aquabac), other
Scotts Ortho	36.0	4.7	Ortho Elementals Insect Killer and Weed Killer products, Tom Cat
Bonide	31.5	4.1	Azadirachtin, pyrethrin, plant oils, other
Certis	29.4	3.8	Azadirachtin, Cydia p, Bt's
Monsanto	28.6	3.7	LCO, <i>Bacillus subtilis</i> ,
Woodstream	22.0	2.8	Safer bioinsecticides from neem, pyrethrin, fatty acids, d. earth
VPG	19.0	2.5	Bioinsecticides based on citric acid, soy oil, copper, d. earth
Summit	12.9	1.7	Bti, Btk, oil
Nufarm	12.5	1.6	Mycoshield, phosphoric acid
S.C. Johnson	12.0	1.6	Flea control based on fatty acids
Brandt	9.9	1.3	Cuprous oxide (\$5M), pyrethrin (\$3M), plant oils (\$2M)
BioWorks	9.6	1.2	Azadirachtin, b subtilis, beauveria bassiana, potassium bicarbonate
Nisus	9.0	1.2	Terro, Niban, Nibor, Cymex, Boracare, Timbor
Central Garden & Pet	8.7	1.1	Moss (fatty acids), insects (pyrethrin), slug and snail (iron phosphate)
BioSafe Systems	8.0	1.0	Hydrogen dioxide/peroxide, peroxyacetic acid, phosphoric acid
NovaSource	6.9	0.9	Kaolin (Surround), calcium polysulfide (Lime Sulfur)
Arysta	6.8	0.9	Polyoxin D (\$3.5M), PGR IV, cydia pomonlla
ABM	5.0	0.6	<i>Trichoderma virens</i> (Sabrex)
Rockwell	4.5	0.6	Intice, Boractin
Wilbur ellis	4.5	0.6	Phosphoric acid, sulfur, calcium carbonate
Plant Health Care	3.4	0.4	Harpin protein (forononetin (Myconate)
Gowan	3.3	0.4	Azadirachtin, pelgaric acid, <i>trichoerma gamsii asperellum</i>
Amvac	2.4	0.3	Azadirachtin, streptomycin, BTi
St. Gabriel Organics	2.3	0.3	Insecticides- milky spore <i>B. popillae</i> ; D. earth; castor oil for moles
Custom Liquid	2.0	0.3	Azadirachtin (Azakaranj)
Tenkoz	1.0	0.1	Pix Plus mepiquat
Plant Protectants	0.6	0.1	Phosphoric acid, chenopodium flocculosa
Other	189.6	24.5	-
Total	773.0	100.0	

In agriculture, it is generally accepted that more than 80% of biopesticides are not used on organic farms, but by producers employing conventional farming practices. Other estimates indicate that only 5% of biopesticides are used in strictly organic production. Biopesticide Products Industry Alliance (BPIA) claims that 97% of biopesticides are used in conventional agriculture. It appears that the benefits of biopesticides are becoming more widely recognized and being used to complement and supplement more conventional pesticides.

This report will focus on those biopesticides which have direct pesticidal activity. Mention will be made of pheromones, as these play a role in certain crops such as tree fruit, but the study does not include pheromones used for insect monitoring. Under seed treatment, rhizobial formulations that contain products that add fungicidal or Plant Growth Regulator (PGR) activity and phosphate microbes that increase root growth will be included, as they play such a significant role in leguminous and other crops.

This report will not cover synthetic plant and insect growth regulators or biological products that primarily provide biostimulation. It also does not cover genetically modified plants or plant incorporated protectants (PIPs), which are classified as biopesticides.

In relation to markets, this report will provide brief descriptions of the major market segments including field crops and seed treatment, fruit, vegetables, forestry, pasture and rangeland, ornamentals/floriculture, mosquito control, and over-the-counter (OTC) products.

MARKET DRIVERS

Market drivers can be divided into several overall categories which will be briefly covered below and in more detail under the different market segments.

Food and Operator Safety

Ecolabels are beginning to proliferate as consumers are increasingly (59%) checking that their food is natural. There are no standards for ecolabels.

Growers have interest in products with zero or very short harvest intervals to satisfy food chain requirements and still achieve adequate pest control. Growers also wishing to export their crops have to consider the requirements of importing countries which frequently have more stringent residue requirements.

Retailers, consumers, and global trade are anxious to meet Minimum Risk Levels (MRLs).

The Food Safety Modernization Act was signed into law in 2011, but aspects of implementation are still under review as of this writing.

Growers are anxious to use products with short re-entry intervals for operator safety.

Regulator and supply chain activity

Regulators are placing increasing restrictions on some of the toxic and more persistent products and often de-listing products, so that the armory of products for use in certain crops is getting very limited.

Regulators do not require so much data, particularly the long studies, for a new biopesticide product to be registered. A year has been reported to gain registration, whereas a synthetic chemical can take two to three times longer.

Regulators have been tightening restrictions on many pesticides by decreasing residue limits, requiring longer pre-harvest intervals and longer worker re-entry intervals. As a result, there is a narrower window for application so that the grower must pay more attention to the timing and application.

Global markets are becoming increasingly important and MRLs are not uniform globally. CODEX is attempting to harmonize for international trade but there are problems in assessing active metabolites.

There are many supply chain certification programs in existence with different standard and requirements.

Corporate sustainability goals

Several companies are aware of consumer concerns about the environmental impact of crop production. McDonalds in the United States has been collecting and sharing examples of best practices for reducing pesticides on potatoes and efforts to find alternative pest control strategies with their shareholders. Several other companies are also aware of the need to demonstrate awareness of such concerns and be seen to be taking active steps to be more sustainable. Baby food producers have been setting much more stringent requirements for chemical use for many years.

Supermarket chains, such as Walmart, are anxious to reduce waste to zero and are trying to understand how the use of biopesticides can contribute to this goal versus conventional chemicals. It is estimated that 30% to 40% of our food is wasted so that there is pressure to reduce this waste by avoiding loss through pathogen and insect attack after harvest. Growers will need to design spray programs that maximize harvests of marketable, if not top-quality crops.

Increase in organic production

There has been growth in organic production, particularly by large growers of both field crops and fresh produce. This topic will be covered in more detail in the special segment on organic production.

Integrated pest management

There is an increasing adoption by producers of integrated pest management (IPM), which requires managed use of pesticides, so that products which affect known predators of the target insect are avoided.

IPM requires careful selection of products that are specific to the targeted insect. For example, specific products for codling moth in apples, oriental fruit moth in stone fruit, and navy armyworm in almonds, pistachios, and others can enable natural predators to keep secondary pests in check, so that specific control measures are not necessary. Secondary pests have natural enemies which must be preserved so avoiding the secondary pest problems.

The successful use of IPM is heavily dependent on knowledge not only of the key target pests but also the desirable species, so that products can be chosen that are selective for the target pest. Biopesticides are not immune from affecting desirable predator species but tend to be more specific. Labels of both conventional and biopesticides must be carefully studied.

Producer concerns about resistance management and being able to use products that can be used to partner or replace conventional pesticides in crop protection programs is important to growers. It is estimated that there are at least 360 fungal pathogen species which have developed some level of resistance to fungicides, some 250 species of weeds to herbicides, and between 600 and 1,000 insects to insecticides. In some crops, the range of conventional fungicides has become restricted due to the resistance factor.

Growers are strongly recommended to monitor their insect and fungal pathogens, apply products when threshold levels are reached at recommended rates specific to the organism, wherever possible to avoid killing desirable predaceous insects, and either alternate or combine products with different modes of action. Increasingly, there are biopesticides which can be timed strategically in the program, combined or alternated with conventional chemicals. The goal of management is to delay the need for resistance management, by using a program with products of varying modes of action so that resistance can be delayed if not avoided completely. Since biopesticides have multiple modes of action, they are ideal components of such a program. An example would be the use of Pristine, Procure, or others with Actinovate, Serenade, or Sonata.

Use of natural predators

In perennial crops there has been increasing use of imported predator species to deal with insects that originated in the country of origin of the crop. Examples include the use of *Trioxys pallidus* for control of the serious walnut aphid. The augmentation of the population of the natural enemy of citrus red scale, *Aphytis melinus*, has been a great success in citrus. In Washington, the use of western predatory mites will manage the spider mite population if these populations are allowed to survive. Such programs are dependent on not using pesticides that kill the predators.

Product performance

Over the years crop protection products have been offering higher levels of control so that any products expecting to gain market share must be able to be used so that similar results can be obtained. Growers are willing to try new products, but they must be given as precise label recommendations as possible, so as to be able to gain the best results. Producers appear also willing to change their timing and method of application if there is a chance of getting improved results.

This willingness to try new products and approaches is encouraging to biopesticide producers who are likely to require different approaches and timing, even spray application.

Biopesticides are being shown to help in managing pests and pathogens that have been difficult to control with current products. Several biofungicides are providing control of bacteria, soil pathogens, and insects like psyllids, that cause zebra chip in potatoes.

Challenges and barriers to increased adoption of biopesticides

- Lack of information
- Limited availability
- Concern about efficacy, cost, and ease of application
- Uncertainty about biopesticide use within conventional agricultural production systems
- Lack of resources for grower training

Limitations of biopesticides

- Usually do not offer 100% protection although no pesticide can truly make this claim
- They are usually preventative rather than curative with few exceptions
- More susceptible to environmental conditions and do not work in extreme conditions
- Do not normally work at high disease or pest pressure
- Defined shelf life and storage conditions
- “Do not make a bad grower a good grower,” (from a university extension specialist)

CALIFORNIA EXAMPLE

California has the most diverse agriculture in the United States and a highly sophisticated method of reporting pesticide use. It is useful to see an overview of the current use of biopesticides in California and indicate the current major products that dominate several of the major crops that are the heaviest users of pesticides.

Insecticides: The most widely used insecticides used in California were abamectin, oils, Bifenthrin, methoxyfenozide, and esfenvalerate.

Fungicides: The five top fungicides in terms of acres treated were pyraclostrobin/boscalid, iprodione, propiconazole, metoconazole, azoxystrobin sulfur. Sulfur accounted for 25% of all reported pesticide use in 2012, mostly to control powdery mildew on grapes and processing tomatoes.

Herbicides: Clearly, contact herbicides dominate herbicides, and no biopesticides are included in the five top products.

The accumulated acres treated with the major biopesticides in California, as reported by the Department of Pesticide Regulation for 2012 (latest data), is revealing.

Table 7: California Biopesticide Acres by Biopesticide, 2012

Active ingredient	Acres	% Of total
<i>Bacillus thuringiensis</i> all subspecies	354,515	12.1
Vegetable oil	266,226	9.1
<i>Bacillus subtilis</i> QST 713	121,517	4.1
Azadirachtin	97,649	3.3
<i>Reynoutria sacalinensis</i>	93,331	3.2
<i>Bacillus pumilus</i> QST 2808	75,674	2.6
<i>Aspergillus flavus</i> AF36	48,833	1.7
Neem oil	42,090	1.4
Hydrogen peroxide	39,181	1.3
All other	1,739,011	61.1
Total	2,932,027	100.0

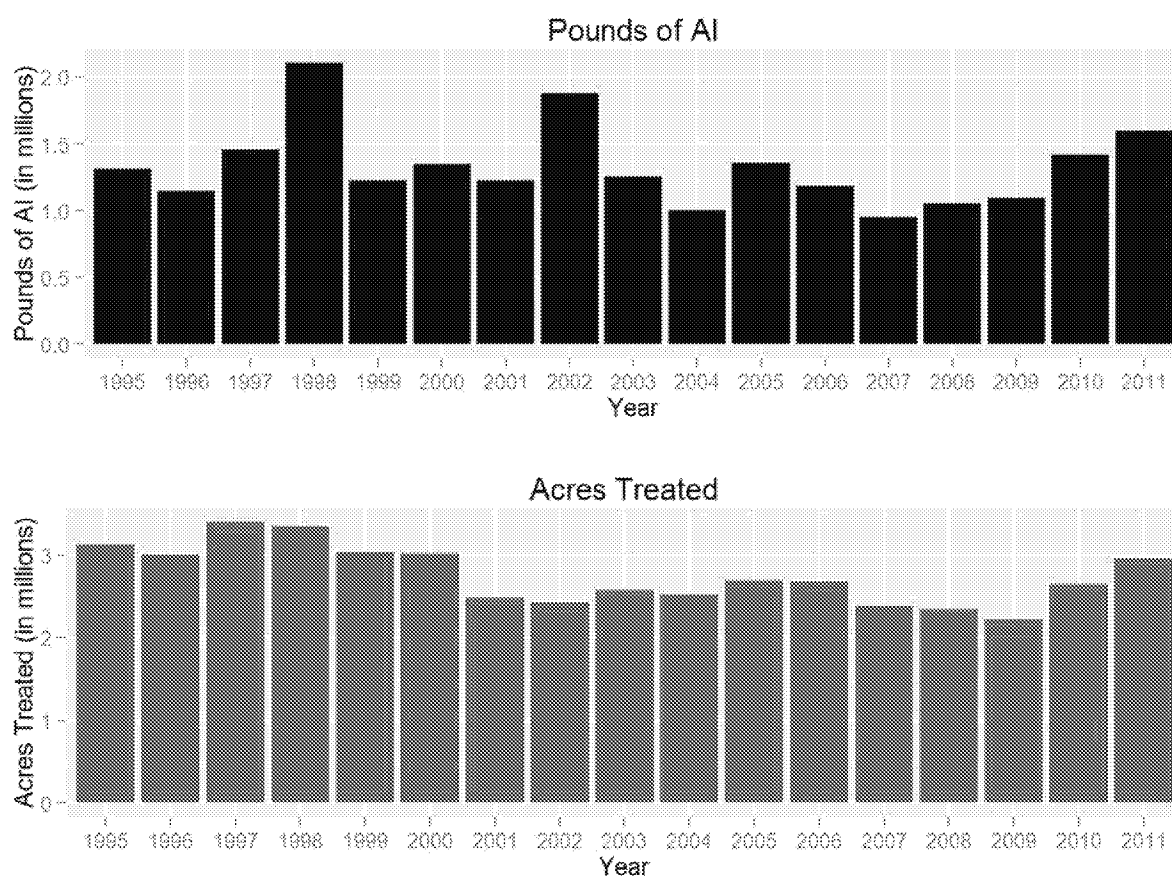
Hydrogen peroxide was used on a total of 21,749 acres, but in 2010 and 2011, 23,208 acres and 39,181 acres were treated, respectively, and the largest crops were grapes, lettuce, celery, tomatoes, and spinach on acreages varying from 2,500 to 4,100 acres.

The two-other major acreage biopesticide products that were not included were gibberellins at 22,518 acres and lactose at 68,215. Limonene is mainly used for cleaning purposes, but is also used as an insecticide and mosquito larvicide on 71,439 acres in 2012.

A total of 170,574,727 lbs. of pesticides was used in California and biopesticide use declined by 241,000 lb. (15%) and 35,500 acres (1.2%) compared to the previous year. The most-used biopesticide active ingredients were *Bacillus thuringiensis* (Bt), combining all species, followed by vegetable oil. A decline in the use of vegetable oil and potassium bicarbonate accounted for most of the decrease in poundage, while the amount of Bt used increased. Most of the decrease in area treated was due to vegetable oil.

The Department of Pesticide Regulation's 2012 database provides the following explanation: "Biopesticides include microorganisms and naturally occurring compounds, or compounds essentially identical to naturally occurring compounds that are not toxic to the target pest (such as pheromones). Reported pounds of active ingredient (AI) applied include both agricultural and non-agricultural applications. The reported cumulative acres treated include primarily agricultural applications. Data are from the Department of Pesticide Regulation's Pesticide Use Reports."

Figure 1: Pounds of Active Substances and Acres Treated with Biopesticides in California, 2012



SOURCE: Figure 8 California Department of Pesticide Regulation, 2012

It is notable that there has been a slightly fluctuating use of biopesticides since 1995, but a steady increase from 2009.

FIELD CROPS

The importance of field crops in U.S. agriculture is well known, and the acreages of corn, and increasingly, of soybeans and wheat, are huge. Corn is produced in every state, but mainly in the Midwest. Soybeans are increasingly produced across the country as the demand for oil, and the byproduct, protein meal, continues to grow. Wheat is produced in the hot and dry Southwest, and also in the Pacific Northwest and other regions with higher humidity. As a result, a range of insects and pathogens affect these crops, depending on geography and climate. Other crops, such as cotton in the south and oilseed rape and sugar beet in the north, have very different profiles for insect and disease control due to their contrasting environments.

Market prices are variable, and margins are thin compared to higher-priced specialty crops, so that input costs must be watched very closely. Genetically engineered traits for weed and insect control have increased the value of corn, soybean, and cotton seeds relative to other inputs. That combination of higher seed value and seed-based crop protection has resulted in major growth in seed treatment as the preferred method of protecting crops against insects and diseases.

Seed treatment utilizes a fraction of the amount of insecticide or fungicide that would have been applied as granules or to the foliage of the young plant. Since seed has become expensive due to technology use fees for GE traits, farmers have been anxious to protect their investment, ensure a good plant stand, and avoid the possibility of having to plant the field again. Seed treatment has become an essential feature of most purchased seed, and is the most rapidly growing segment of the crop protection business.

The use of fungicide sprays is minimal in field crops, except in some wheat growing areas. Insecticide use is standard in cotton and increasing in wheat, fallen off in corn, and usually happens according to infestation levels in all other crops.

However, biopesticide use in field crops has been primarily as seed treatments. The market described here as biopesticides on field crops is entirely made up of seed treatment products. Sales volume figures are based on distributor interviews and are most valid at the overall field crop level. Data was collected mainly at the active ingredient and company levels. Sales by brand and crop should be considered general estimates.

There are a number of biopesticide products used in field crops that have sales estimated to be greater than \$200,000. The "major supplier" column is the supplier of record in the product sales data. The suppliers listed as other are often part of the supply chain rather than originators. Many other products are listed, but sales are either very low or not identifiable.

Table 8: Examples of Biopesticides Used in Field Crops in the United States with Estimated Sales Over \$200,000, 2016

Active	Brands	Major supplier
<i>Azadirachtin</i>	Azatin	Certis
<i>Bacillus cereus/mepiquat</i>	Pix Plus	Tenkoz
<i>Bacillus firmus</i> I-1582	Votivo (mix w/Poncho)	Bayer
<i>Bacillus subtilis</i>	Subtilex, HiStick, Vault HP	BASF
<i>Bacillus subtilis</i>	Kodiak HB, System 3, Companion, Sting	Bayer
<i>Bacillus thuringiensis</i>	Dipel, Biobit, Foray	Valent
<i>Bt Israelensis</i>	Aquabac	BASF
<i>Heliothis zea</i> NPV	Gemstar	Certis
<i>Lipto-chitooligasaccharide (LCO)</i>	Optimize 400, Ratchet	Monsanto
<i>Pasteuria nishizawae</i>	Clariva	Syngenta
<i>Pyrethrin</i>	Pyrenone	BASF
<i>Steinemema</i>	Nemasy, Millenium	BASF
<i>Trichoderma</i>	Sabrex, Bio-Cure-F	ABM
<i>Trichoderma</i>	Root Shield, Turf Shield, Plant Shield, T-22	BioWorks

BIOPESTICIDE SALES BY CLASSIFICATION

Biopesticide sales to the field crops sector total \$236.9 million in 2016 at the end-user level. Microbes dominates sales of biopesticides to the field crops sector, accounting for \$213.3 million, or 90.0% of the field crop market. The largest use of biopesticides in field crops is as a nematocide, followed by uses as insecticides.

FIELD CROP SALES BY ACTIVE SUBSTANCE

Bacillus firmus is by far the leading biopesticide active substance, with sales of \$130 million at end-user level, or 54.9% of the market. The product is sold as Votivo and combined with Poncho as a seed treatment, mainly on corn, which accounts for \$120 million or 93% of sales. Other important crops on which Votivo is applied are soybeans at \$9 million, and cotton at \$1 million. Growth is expected on both soybeans and cotton. Other important field crop actives are *Bacillus subtilis* and its mixtures at \$49 million or 20.7% of total market, and LCO and its mixtures at \$17 million and 7.2%. *Aspergillus flavus* and *Trichoderma* (all species) follow, with a market share of 2.7% and 2.1%, respectively.

Table 9: Field Crop Sales in the United States by Biopesticide Classification, 2016

Biopesticide classification	\$ Thousand	Representative brands	% Of total
MICROBES			
Fungicides	71,700	Subtilex, Kodiak, System 3, HiStick, Vault	30.3
Insecticides	800	Dipel Foray, Nolo bait	0.3
Nematicides	135,000	Votivo (mix w/Poncho)	57.0
Herbicides	300	Devine	0.1
PGR	5,500	Jumpstart, MicroAz,	2.3
Total	213,300		90.0
FERMENTATION PRODUCT	19,500	Optimize, Proact, N-hibit, Myconate	8.2
BOTANICAL	1,200	Azatin, Molt-x, Cue, Simplex	0.5
VIRUS	300	Gemstar HPV, Helicovex	0.1
ALL OTHER	2,600	Nemasys, Millenium, Offshoot	1.1
TOTAL	236,900		100.0

Table 10: Field Crop Biopesticide Sales in the United States by Active Ingredient, End User Level, 2016

Active	Brands	\$ Thousand	% Of total
<i>Bacillus firmus</i> I-1582	Votivo (mix w/Poncho)	130,000	54.9
<i>Bacillus subtilis</i> (and mixtures)	Quickroots, PPST, Companion	49,500	20.9
LCO (and mixtures)	Optimize, Jumpstart, Vault HP, Kodiak HB, Sting, Companion	19,000	8.0
<i>Aspergillum flavus</i>	Alfaguard	6,500	2.7
<i>Bacillus licheniformis</i>	Marauder	5,000	2.1
Harpin Protein	Proact, N-Hibit, Messenger	2,400	1.0
<i>Trichoderma</i> (all)	Sabrex, Bio-Cure-F, Rootshield, BioTam	2,200	0.9
<i>Conothyrium minitans</i>	Contans	1,400	0.6
<i>Bacillus cereus</i>	Pix Plus	1,000	0.4
<i>Agrobacterium radiobacter</i>	Gallex, Gallitrol	1,000	0.4
<i>Bacillus amylolquefaciens</i>	Avonni	500	0.2
<i>Azospirillum</i>	Micro Az, Az Green	500	0.2
Azadirachtin	Molt X	400	0.2
<i>Heliothis zea</i> NPV	Gemstar	100	-
All other		17,400	7.3
Total		236,900	100.0

SALES BY SUPPLIER

Of the total market on field crops of \$236.9 million, Bayer is by far the leading supplier. Bayer sales total \$130.1 million, or 54.9% of the total sector. Bayer's sales are primarily based on *bacillus firmus* and sold as Votivo seed treatment, primarily as a corn seed treatment. BASF is the second-leading supplier with sales of \$41 million based on *bacillus subtilis* and LCO as a seed treatment. Monsanto is the third-leading company with \$28.5 million in sales, as a seed treatment. Syngenta follows in fourth place with sales of \$11.5 million.

Table 11: Biopesticide Sales on Field Crops in the United States by Supplier, End User Level, 2016

Supplier	Active material	\$ Thousand	% Of total
Bayer	<i>Bacillus pumilus</i> , <i>bacillus firmus</i>	130,100	54.9
BASF	LCO, <i>Bacillus subtilis</i>	41,000	17.3
Monsanto	LCO, <i>Bacillus subtilis</i>	28,500	12.0
Syngenta	<i>Pasteuria nishizawae</i> , <i>aspegillum flavus</i>	11,500	4.9
Valent (Novozymes)	<i>Streptomyces lydicus</i>	6,000	2.5
ABM	<i>Rhizobia</i> , <i>Bacillus licheniformis</i>	5,000	2.1
Plant Health	Harpin protein, <i>formononetin</i>	2,500	1.1
BioWorks	<i>Trichoderma harzianum</i> , <i>azadirachtin</i>	2,100	0.9
Arysta (Chemtura)	<i>n-decanol</i> , <i>malaeic hydrazide</i>	1,700	0.7
Tenkoz	<i>Bacillus ceres/mepiquat</i>	1,000	0.4
Drexel	6-HP	900	0.4
All other		6,600	2.8
Total		236,900	100.0

FIELD CROP BIOPESTICIDE SALES BY CROP

In 2016, nearly all the biopesticide use in field crops is on corn. The group of products used on corn accounted for 77% of the total field crop biopesticide use.

Table 12: Field Crop Biopesticide Sales in the United States by Crop, End User Level, 2016

Crop	Brand(s)	\$ Thousand	% Of total
Corn	Azatin, Votivo, Harpin	182,413	77.0
Soybeans	Saberex, Bio-Cure, Dipel, Foray, Pix Plus, RootShield, Clariva, Votivo	26,296	11.1
Cotton	Subtilex, HiStick, Vault, Kodiak, Votivo	11,134	4.7
All other	Nemasys, Millenium, Root Shield	17,057	7.2
Total		236,900	100.0

CROP PESTS AND TRADITIONAL CHEMICAL TREATMENTS

Clients have requested that Kline includes information on pests and the chemical competition faced by biopesticides in each crop, thereby indicating the potential upside for high-performance biopesticides. Kline presents the information for corn, soybeans, and cotton, the three field crops in which biopesticides are used heavily, as well as further indicates the primary fungal pathogens and insects.

CORN DISEASES

A complex of fungal and bacterial pathogens can cause rotting of the seed, and injury and death of the developing seedling. Seed rots affect seeds prior to or shortly after germination. If quality seed is used, and good planting conditions exist, with soil temperatures above 50°F to 55°F, germination should occur rapidly, and there is little time for pathogens to cause injury.

Seedling blight or damping-off affect seedlings prior to emergence, or while the seedling is up to the second or third leaf stage. Poor quality seed, cool and wet conditions, poorly drained fields, and compacted soils may delay germination and emergence, providing plenty of time for infection. Many of the pathogens overwinter in the plant debris and are more prevalent under no-till and reduced tillage regimes.

Respondents mentioned *Rhizoctonia* (*Rhizoctonia solani*) and *Pythium* species as the major seedling diseases that could cause problems. Other pathogens that can cause seed rotting and damage to corn seedlings include *Fusarium spp.*, *Diplodia* (*Stenocarpella*), *Penicillium* blight (*Penicillium spp.*), *Gibberella*, *Trichoderma*, *Aspergillus* and two bacteria, *Holcus* Spot (*Pseudomonas*) and Stewart's Wilt (*Erwinia stewartii*).

Most of these organisms live and flourish in the soil and infect a wide range of crops and plants. *Pythium* exists in the soil, but other organisms, such as Anthracnose (*Colletotrichum graminicola*), can be present in the seed, cause seedling blight, and affect final yield, because of stalk rot and leaf blight.

Seed companies are constantly reviewing new fungicides and combinations of different fungicides, to ensure the most complete protection from fungal pathogens resulting from seed- and soil-borne infection. Respondents to this study did not mention any use of additional treatment of seed, as in cotton, either by the seed company or on the farm.

Corn fungicides

Most of the fungicide treatments are chemical fungicides. Chemtura's Kodiak *Bacillus subtilis* is the exception, and offers control of *Fusarium spp.* which produces the fumonisin toxin. Seed treatment provides an excellent means of introducing the bacteria into the plant in an extremely convenient way. The bacteria thrive in the corn plant, fill up the intracellular spaces of the corn plant, and repel the fungus. There are other biological products that are labeled for corn.

Seed companies have always screened new hybrids for resistance or tolerance to fungal pathogens, and farmers are advised to select hybrids with a good genetic disease package. The more recent development has been the genetic engineering of insect-resistant traits for corn borer and rootworm, and the use of neonicotinoid insecticides, to complement these trait(s) and provide control of both soil and early foliar insects. The seed has become the vehicle to deliver, not only the yield potential of the crop, but also critical functions that were previously provided by either soil- or foliar-applied crop protection chemicals.

Corn insects

There are many important soil insect pests which can cause serious injury to corn plants and reduce plant stand. The various species of corn rootworm are usually considered to be the most damaging, and their control has historically been the reason for the large corn soil insecticide market. The introduction of corn rootworm resistant hybrids revolutionized control. Wireworms, white grubs, black cutworms, and seed corn maggots can be problems, but except for seed corn maggot, their incidence is difficult to predict.

Sugarcane beetles appear to have become more prevalent, and neither thiamethoxam nor imidacloprid provide control, but the Poncho 600 clothianidin label does indicate control even at the 0.25 to 0.5 mg ai/kernel rate.

Additional insects, which can affect corn roots and the developing seedling, include corn root aphid, grape Colaspis, seed corn beetle, slender seed corn beetle. Insects that feed on the developing seedling and young plant include corn leaf aphid, corn leafhopper, thrips, corn flea beetle, and chinch bugs.

Corn insecticides

Neonicotinoid insecticide seed treatments have been found to provide control both of soil pests and early foliar insects. Labels typically cover a wide range of these insects. The two neonicotinoids used for seed treatment are clothianidin and thiamethoxam.

Table 13: Brands, Percent Active Ingredients, Company, and Recommended Use Rates for Fungicides in Corn in the United States, 2016

Brand	Active ingredient(s)	Company	Product use rates per 100 lb
Acceleron DC-309	28.35% metalaxyl	Monsanto	0.750 fl oz
Acceleron DC-509	40.7% ipconazole	Monsanto	0.085 fl oz
Acceleron DX-709	22% trifloxystrobin	Monsanto	0.320-0.640 fl oz
Acquire	29.99% metalaxyl	BASF	0.100–0.750 fl oz
Allegiance FL, Sebring 2.65 ST, Dyna-Shield metalaxyl Metastar ST, Belmont 2.7FS	28.35% metalaxyl 2.65 lb./gal 28.98% metalaxyl	Bayer, Nufarm Loveland Chemtura	0.100 – 0.375 fl oz 0.100 fl oz
Apron XL	33.3% mefenoxam	Syngenta	0.0425–0.085 fl oz
Baytan 30	30% triadimenol	Bayer	3.000 fl oz
Captan 400	37.4% captan	Bayer	1.250–2.750 fl oz
Dithane and others	37-80% mancozeb	Dow and others	Liquid and dry
Dynasty	9.6% azoxystrobin	Syngenta	0.153 fl oz
Kernel Guard Supreme	14% carboxin	Chemtura	1.500 oz./42.000 lb
Kodiak HB	0.3% Bacillus subtilis GB03	Chemtura	4.000 oz
Maxim 4FS, Spirato 480 FS	40.3 fludioxonil	Syngenta, Nufarm	0.080–0.160 fl oz
Maxim Quattro	3.32% fludioxonil + 2.65% mefenoxam + 1.33% azoxystrobin + 26.5% thiabendazole	Syngenta	0.390–0.530 fl oz
Maxim XL	21% fludioxonil + 8.4% mefenoxam	Syngenta	0.710 fl oz./80,000 kernels
Mertect 340 F	42.3% thiabendazole	Syngenta	0.170 – 2.600 fl oz
Metlock,	40% metconazole	Valent	0.045-0.090 fl oz
Raxil 2.6F, Sativa 309 FS	28.3% tebuconazole	Bayer, Nufarm	0.075-0.740 fl oz
Signet 480 FS	44% thiram	Bayer	1.500 fl oz/bushel
Stamina F ³ HL	7.57% pyraclostrobin + 7.57% triticonazole + 4.54% metalaxyl	BASF	1.000 fl oz 0.440 fl oz/80,000 kernels
Trilex	22% trifloxystrobin	Bayer	0.320 fl oz–0.640 fl oz
Vortex	40.7% ipconazole	Bayer	0.044 fl oz

Corn nematodes

Trials and extensive farm field surveys have confirmed that nematodes can cause early injury to corn, with an economic impact on the final yield. More than 50 species of nematodes are known to feed on corn in the United States, but dagger, lance, lesion, needle, ring, root-knot, spiral, sting, stubby, and stunt nematodes are the major genera.

Recommendations have existed for many years for the in-furrow at planting application of insecticides, but the use of granules at planting has declined very significantly with the introduction of insect-resistant traits. As soil treatment drops off, seed treatment offers a convenient method of providing early protection to the vulnerable seedling.

Originally, the scientific community was not convinced about the value of nematicides as an integral part of a corn seed package. However, Bayer's Poncho/VOTIVO has gained 20.5% market share over the past few years and has proven its value.

Corn nematicides

There are many leading brands of seed treatment insecticides. A wide range of products are registered and labeled for use in corn, but very few are used by the seed companies to treat corn seeds.

SOYBEAN DISEASES

A range of diseases affect soybean production by causing losses in the soil and reducing plant stand and final yield through seedling losses. A survey carried out in 2010 indicated that soybean cyst nematode was the most serious pathogen problem in soybeans, reducing the national crop by 116.1 million bushels. Seedling Diseases came next at 56.0 million bushels, Phytophthora for 38.8 million, and Root Rot at 10.6 million. Total disease losses were 478.3 million, so soybean cyst nematode at 24.2%, followed by seedling disease at 11.7%, represented over one-third of the total loss.

Since climatic and soil conditions vary from year to year, it is difficult to forecast which diseases will be troublesome during that season. Since there is no varietal resistance to Rhizoctonia root rot and Pythium, seed treatment with a broad-spectrum product ensures that protection will be achieved whatever the labeled pathogen.

Table 14: Selected Brands, Percent Active Ingredients, Company Labeling, and Use Rates for Products with Insecticides, including Nematicides and Fungicides in Corn in the United States, 2016

Brands	Active ingredient(s)	Company	Use rates
Acceleron IC-609	48% clothianidin	Monsanto	0.2500-0.5000, 1.25 mg ai/seed
Acceleron IX-409	48.7% imidacloprid	Monsanto	0.1600-1.3400 mg ai/kernel
Avicta Complete Corn 250	11.7% thiamethoxam 10.3% abamectin 2.34% thiabendazole 0.30% fludioxonil 0.23% mfenoxam 0.12% azoxystrobin	Syngenta	4.3000 oz/80,000 kernel 0.4600 oz/80,000 kernel
Avicta Complete Corn 500	23.1% thiamethoxam 10.2% abamectin 2.31% thiabendazole 0.30% fludioxonil 0.23% mfenoxam 0.12% azoxystrobin	Syngenta	1.1800 oz–20.2000 oz./100 lb seed
Avicta Duo Corn	12.4% abamectin + 28.1% thiamethoxam	Syngenta	0.2000–0.2500 mg ai/kernel 0.4538–0.5672 mg ai/seed
Cruiser 5FS	47.6% thiamethoxam	Syngenta	0.2500–0.8000 mg ai/kernel 1.2500 mg ai/kernel for rootworm
Cruiser Maxx 250 (Contains Maxim Quattro and Cruiser 5FS)	3.32% fludioxonil 2.65% mfenoxam 1.33% azoxystrobin 26.50% thiabendazole 47.6% thiamethoxam	Syngenta	Cruiser 5FS - .21 lb/75,000 kernels Maxim Quattro - .39-.53 fl.oz/80,000 kernels
Concur	25% imidacloprid + 1.0% metalaxyl	Winfield Solutions	1.80 oz/100 lbs
Dyna-Shield Imidacloprid 5	48.7% imidacloprid	Loveland	0.1600–1.3400 mg ai/kernel 0.7200–6.0000 fl oz/80,000 units of seed
Gaucho 600	48.7% imidacloprid	Bayer	0.1600–1.3400 mg ai/kernel 0.7200– 6.0000 fl oz/80,000 units of seed
Kernel Guard Supreme	10.42% permethrin + 14.00% carboxin	Chemtura	3.5700 oz/cwt
Latitude	25% imidacloprid + 14% carboxin + 1% metalaxyl	Chemtura	3.5700 oz/cwt
Poncho 600	48.0% clothianidin	Bayer	0.2500–1.2500 mg ai/kernel 1.1300–5.6400 fl oz./80,000 seed unit
Poncho/VOTIVO	40.3% clothianidin + 8.1% <i>Bacillus firmus</i> I-1582	Bayer, Monsanto	0.5000 mg ai/seed 2.7000 fl oz/80,000 seeds

The use of seed treatment protects the seed and developing seedling, to ensure optimal emergence and plant stand, but does not provide control of foliar pathogens, such as leaf spot (*Cercospora spp.*) and leaf rust.

There has been increased interest in providing protection through fungicide seed treatment, as a result of the trend to earlier planting, greater vulnerability to seedling diseases, and the need to ensure uniform and optimal plant stands. This has been recognized by seed companies, who are now offering treated seed, by dealers offering seed treatment services, and by growers anxious to ensure optimal plant populations and avoid replanting in cases of heavy loss.

Since there is no single active ingredient that can control all the soil borne diseases that can affect seedling survival and development, it has been shown that a combination of fungicides is needed to control all the pathogens that could be damaging.

It is not usually easy to determine the causal organism for seedling diseases, as the complex of *Pythium*, *Fusarium*, *Rhizoctonia*, and *Phytophthora* is usually present.

Important soil-borne diseases and fungicides used in soybeans include:

Pythium seed decay, damping-off, and root rot (*Pythium spp.*) are very widely distributed soil pathogens that can attack a range of crop plants. There are five major species, but recent work has shown that there may be 30 to 40 individual species. Young seedlings, up to 10 days, are particularly susceptible to *Pythium*. In Kentucky, *Pythium ultimum* was found to be associated with 75% of the seed emergence problems in cool and wet soils.

At present, control is provided by two fungicides: mefenoxam and metalaxyl. Plant breeding has not been able to help, as there is only one gene that provides some partial resistance to *Pythium*.

Seed treatment is effective with active ingredients, such as mefenoxam and metalaxyl, in protecting the seedling during the critical first two weeks or so.

Fusarium seedling blight (*Fusarium oxysporum* and *F. solani* and others) consists of a complex of different diseases, some primary and some opportunistic, causing seedling blight and root rot of soybeans. As with *Pythium*, the fungus survives as overwintering bodies (chlamydospores in this case) or mycelium, which can then attack the developing seedling, and cause death and reduced plant stand. Damage from *Fusarium* may be more severe when it occurs in combination with other diseases or plant stress.

Cultural practices that ensure quick germination and seedling development are recommended. Seed treatment with fludioxonil, azoxystrobin, captan, carboxin, and others is recommended.

Fusarium solani, synonym *Fusarium virguliforme*, is the causal organism of Sudden Death Syndrome (SDS), which is one of the most important diseases of soybeans in the Midwest. It has been identified in most states in the North Central region, from Ohio and Tennessee to Nebraska, Kansas, Mississippi, and Minnesota. The disease is most severe when soybeans are planted early in cool, wet soils. Symptoms are also more serious when *Fusarium* and Soybean Cyst Nematode (SCN) are both present, as in at least half of Indiana's fields. In Kline's research, it was noted that Bayer was searching for compounds with higher levels of efficacy on *Fusarium*.

Seed treatments and in-furrow fungicide applications have only limited effect, and resistant varieties are being developed. Good drainage is critical, so no-till may be beneficial for some soil types, but not in others. Rotation has not been shown to be particularly helpful. Improved drainage, varieties with any SDS (Sudden-death-syndrome) and SCN (Soybean Cyst Nematode) resistance, and later plantings are the only management tools available at present for control.

Rhizoctonia root and stem rot (*Rhizoctonia solani*) is a soil-borne fungus, which is primarily a seedling disease that attacks the basal stem and roots of young plants, and causes pre- and post-emergence damping off. It is very common, and infects a wide range of crops, and it is considered to be particularly problematic in soybeans if cotton was the previous crop. There are indications that this disease is also increasing in prevalence.

It is one of the easier diseases to diagnose, because of the signature reddish-brown lesions on the stems and root damaged. Infection occurs in the same way as has been described for the previous fungi: the fungus survives in the soil as either sclerotia or resting mycelium in plant debris. Moist conditions are required to activate the fungus so that it can colonize soybean seeds, roots, and stem tissue.

Control of *Rhizoctonia* root and stem rot is similar to *Pythium*. Seed treatment with fludioxonil, azoxystrobin, and others is recommended. There are currently no resistance or tolerance genes for the control of *Rhizoctonia*.

Phytophthora root and stem rot (*Phytophthora soave*) is considered to be the most damaging soybean disease in the upper Midwest, especially in South Dakota, causing 4% to 6% loss each year. Losses from this pathogen were estimated to be 39 million bushels in 2005. In Ohio, the fungus can infect all stages of growth, from rotting of the seed, damping-off of the developing seedling and root, and stem rot of the emerged plant, resulting in ultimate death. It is distributed throughout the soybean growing region, but is most prevalent in wet areas, particularly fields with poor internal drainage. This pathogen is serious in Minnesota. The disease may be more prevalent in more intensively grown soybean rotations.

Seed treatment with a fungicide, such as metalaxyl or mefenoxam, is recommended to provide protection during the critical germination and seedling development stages.

Soybeans-other soil-borne diseases

There are several other diseases which affect soybeans, but they were not specifically mentioned by respondents as being of economic significance at least on a regular basis.

Charcoal rot (*Macrophomina phaseolina*) is widely distributed in soils, and attacks a number of crops, including soybeans. The organism is more normally associated with mid- to late-season disease symptoms, but seedlings can become infected and the plant may die.

Cultural practices to prevent charcoal rot include planting non-host crops, such as cereals, and using irrigation during periods of stress. Trials have indicated that a combination of chloroneb + mefenoxam, with or without thiabendazole, and the combination of mefenoxam + fludioxonil + *Bacillus subtilis* can reduce seedling loss from charcoal rot disease.

Brown stem rot (*Phialaphora gregata*) is considered a minor disease problem in the North Central region but it can cause up to 30% yield loss. While seedlings are infected early, disease symptoms do not appear until the plant starts to age. Some soybean resistant varieties are resistant to brown stem rot.

Seed treatment has not been found to be effective.

Sclerotinia stem rot and white mold (*Sclerotinia sclerotiorum*) affects a very wide range of plants. Sclerotia in the soil are highly resistant, and produce airborne ascospores, which infect the lower canopy of the plants. White mold can also be carried by seed, in addition to inoculum in the soil, which results from the sclerotia on plant debris from infected soybeans that were grown as long as seven years ago. Cool, wet weather favors this diseases with symptoms that include wilting and death.

The seed should be well-cleaned, to remove the sclerotia, and treated with active ingredients, such as fludioxonil and thiram, and ensure certified disease-free seed.

Soybean seed-borne diseases

Phomopsis seedling blight (*Diaporthe phaseolorum* var. *sojae*, *Phomopsis longicolla*) is carried on the seed and can cause seed decay and seedling blight. Damage is most severe in wet seasons, when harvest is delayed. Infected seeds produce low quality oil and meal.

Control is best achieved by ensuring that the seed is disease-free. Seed treatment with active ingredients, such as fludioxonil, captan, or carboxin is recommended.

Anthracnose (*Colletotrichum truncatum*, among others) is seed-borne and pre- and post-emergence damping off may occur when infected seeds are planted. Foliar symptoms develop later, which may ultimately result in premature defoliation.

Purple seed stain, purple blotch (*Cercospora kikuchii*) is present in the seed coat of infected seeds, so that it can develop and infect the cotyledons and stem. The young plant may be killed at an early stage or develop further and cause leaf blight symptoms at the beginning of seed set. Infected seeds have a high level of discoloration, lower oil content, and reduced germination percentage.

Some degree of resistance to the seed and/or leaf phases of the disease has been introduced into some soybean cultivars. Disease-free seed should be used. Seed treatment is not specifically recommended.

Soybean seed treatment products

The following is a list of well-known seed treatment products that are available for soybeans.

Pioneer offered premium seed treatment packages for soybeans: Evergol Energy, Allegiance, an insecticide; PPST 203, a proprietary biological/polymer; and PPST 120+ - a rhizobia inoculant/extender.

Soybean insects

Historically, insecticides have not been used in soybeans to control soil-borne or early foliar insects that also transmit yield-depressing virus. Aphids were only detected in North America in 2000, and the later planting of soybeans may have been largely responsible for the lack of interest in early control of this insect. Soybean aphids have now been reported in most soybean growing states, from Mississippi and North Dakota, to Wyoming and Georgia. Other insects include bean flea beetle and corn seed maggots.

Currently, the combination of the increasing interest in fungicide seed treatment, availability of neonicotinoid insecticides, threat from aphids, and the trend to earlier planting have offered the opportunity to provide a package of products controlling both pathogens and early insects.

Bean leaf beetle (*Certoma trifurcata*) overwinters under leaf litter in wooded areas or under untilled soybean debris. The adults that have survived the winter emerge and eagerly colonize soybean seedlings, which are their preferred feeding sites. No-till may provide a more favorable environment for bean leaf beetles to overwinter due to the greater amount of crop residue.

Bean leaf beetle has also been shown to be the vector of bean pod mottle virus (BPMV), which can cause yield reduction and discolored soybeans, which may result in dockage when delivered for marketing.

Table 15: Selected Brands, Active Ingredients, Company, and Labeled Use Rates for Fungicides for Seed Treatment in Soybeans in the United States 2016

Brand	Active ingredient	Supplier	Use rate per 100 lb
Acceleron DX-109	18.40% pyraclostrobin	Monsanto	0.40-1.50 fl oz
Acceleron DX-309	28.35% metalaxyl	Monsanto	0.80 -1.50 fl oz
Acceleron DX-612	Fluxapyroxad	Monsanto	0.24 fl oz
Acceleron Fungicide	Pyraclostrobin Metalaxyl Fluxapyroxad	Monsanto	2.24 fl oz
Acceleron DX-612	28.7% fluxapyroxad	Monsanto	0.24-0.47 fl oz
Allegiance FL, Sebring 2.65 S, MetaStar ST	28.35% metalaxyl	Bayer, Nufarm, Chemtura	0.75–1.50 fl oz
Dyna-Shield Metalaxyl	28.35% metalaxyl	UAP	0.75–1.50 fl oz
Allegiance Dry	12.50% metalaxyl	Chemtura	1.50–2.00 oz
Apron XL LS	33.30% mefenoxam	Syngenta	0.16–0.64 fl oz
Apron MAXX RFC	2.31% fludioxonil + 3.46% mefenoxam	Syngenta	1.50 fl oz
Apron MAXX RTA	1.10% mefenoxam + 0.73% fludioxonil	Syngenta RTA	5.00 fl oz
Bean Guard Allegiance	24.45% captan + 12.50% carboxin + 3.75% metalaxyl + 11.9% molybdenum	Chemtura	2.00 oz/bushel
Belmont 2.7 FS	28.98% metalaxyl	Chemtura	0.75-1.50
Captan 400	37.4% captan	Bayer	1.25-2.35 oz
Catapult XL	30% chloroneb + 1.95% mefenoxam	Winfield Solutions	11.75 fl oz
Coronet	Boscalid + pyraclostrobin	BASF	-
Dynasty	9.60% azoxystrobin	Syngenta	0.15–0.46 fl oz
Enhance	20% captan + 20% carboxin +	Chemtura	5.00 oz
EverGol Energy	7.18% prothioconazole + 3.59% penflufen + 5.74% metalaxyl	Bayer	1.0 fl oz
Hi Moly/Captan	50% captan + 10.20% molybdenum	Chemtura	3.30 oz
Kodiak HB GBO3	0.30% <i>Bacillus subtilis</i>	Chemtura	4.00–8.00 oz
Maxim 4FS	40.30% fludioxonil	Syngenta	0.08–0.16 fl oz
Mertect 340-F	43.30% thiabendazole	Syngenta	0.08–0.16 fl oz
(Continued)			

Table 15: Selected Brands, Active Ingredients, Company, and Labeled Use Rates for Fungicides for Seed Treatment in Soybeans in the United States 2016

Brand	Active ingredient	Supplier	Use rate per 100 lb
Protector-D	35.00% thiram + 10.00% molybdenum	Chemtura	3.3 oz
Protector – L –Allegiance FL	14.29% thiram + 1.61% metalaxyl	Chemtura	6.70 fl oz
Rancona 3.8F	40.7% ipconazole	Chemtura	0.085 fl oz
Rancona Summit	0.90% ipconazole + 1.44% metalaxyl	Chemtura	4.00 fl oz
Sebring	30.14% metalaxyl	Nufarm	0.75-1.5 fl oz
Spirato	40.3% fludioxonil	Nufarm	0.08-0.15 fl oz
Thiram 42-S	42% thiram	Bayer	2.0 fl oz
Trilex 2000	7.12% trifloxystrobin + 5.69% metalaxyl	Bayer	1.00 fl oz
Trilex Flowable	22.00% trifloxystrobin	Bayer	0.124-0.224 fl oz 140,000 seeds
Vibrance	43.7% sedexane	Syngenta	0.075-0.16 fl oz
Warden RTA	2.15% mefenoxam + 0.72% fludioxonil	Winfield Solutions	5.00 fl oz

Protection is needed for the emerged seedlings, and seed treatment with thiamethoxam or imidacloprid has been shown to be effective.

Aphids (*Aphis glycines*) in soybeans are a recent phenomenon, but populations appear to have been building up quite rapidly. Aphids were first noted in Wisconsin in 2000, and are now confirmed in 19 other soybean-producing states. The threshold for treatment has been established when 80% of plants have reached the level of 250 aphids per plant. The soybean aphid is the vector of Soybean Mosaic Virus (SMV).

Seed treatment with a neonicotinoid, such as thiamethoxam, has been shown to keep the aphid population in check for about 60 days. A subsequent foliar spray of an appropriate aphicide may be required if aphid populations reach the threshold level in July, unless insecticide seed treatment has been used for late planted soybeans.

Seed corn maggot (*Delia platura*) can be damaging to early planted soybeans, particularly when cover crops are grown and tilling rather than herbicides are used.

Soybean insecticides

Syngenta has pioneered this market with its CruiserMaxx and now offer several variations, such as CruiserMaxx Advanced, which suppresses seed-borne Sclerotinia and Phomopsis species, and a further two or three other CruiserMaxx brands.

Yield increases from insecticide/fungicide seed treatment are inconsistent. However, insecticide seed treatment has been increasing, driven by seed companies and the recommendation to do everything possible to protect the young seedling from pathogens and early insect injury.

Soybean nematodes

Nematodes have been recognized as causing serious crop losses in soybeans. Resistant varieties have been the major defense against CSN, but there are concerns that tolerant strains may be developing. Other genera include root-knot, reniform, stubby-root, sting, stunt, and lance nematodes, so that the resistant varieties only provide protection from CSN.

COTTON DISEASES

Cotton seedlings are particularly sensitive to soil diseases during the germination and early seedling stages. Seedling diseases are caused by a complex of soil fungi, which can occur on their own, but are often found in combination.

All seed companies treat their seeds with a fungicide combination that provides protection from the major fungal pathogens. Overtreatment with additional fungicide is also offered as an option as is one of the seed treatment nematicides: abamectin, thiodicarb, and Votivo *Bacillus firmus*.

Table 16: Selected Brands, Active Ingredients, Company, and Labeled Use Rates for Insecticides and Insecticide /Fungicide Combinations for Seed Treatment in Soybeans in the United States, 2016

Brand	Active ingredient	Supplier	Use rates per 100 lb
Acceleron IX-409	48.70% imidacloprid	Monsanto	1.60-3.20 fl oz
Acceleron Fungicide + Insecticide	pyraclostrobin + metalaxyl + fluxapyroxad + imidacloprid	Monsanto	Individual product rates
Attendant 480	40.23% imidacloprid	Chemtura	200-.4.00 fl
Cruiser 5FS	47.60% thiamethoxam	Syngenta	1.28 fl oz
Cruiser Maxx	22.60% thiamethoxam + 1.70% mefenoxam + 1.12% fludioxonil	Syngenta	3.00 fl oz
CruiserMAXX Advanced	21.50% thiamethoxam + 3.21% mefenoxam + 1.07% fludioxonil	Syngenta	4.00 fl oz
Dyna-Shield Imidacloprid S	48.70% imidacloprid	UAP	1.60-3.20 fl oz
Enhance AW	20.0% imidacloprid + 20.0% carboxin + 20.0% captan	Chemtura	5.00 oz
Equity	22.61% thiamethoxam + 1.70% mefenoxam + 1.12% fludioxonil + 2.13% thiabendazole	Loveland	3.00 fl oz 1.40 fl oz/140.000 seeds
Evergol Energy	7.18% prothioconazole + 5.74% metalaxyl + 3.59% penflufen	Pioneer/Bayer	Individual products
Gaucha 600, Senator 600FS, Attendant 600	48.70% imidacloprid	Bayer, Chemtura, Nufarm	1.60-3.60 fl oz
INOVATE Seed System	14.34% clothianidin + 0.72% ipconazole + 1.15% metalaxyl	Valent, Chemtura	4.74 fl oz
Kernal Guard Supreme	14.00% carboxin + 10.42% permethrin	Chemtura	3.00 oz
Latitude	14.00% carboxin + 1.00% metalaxyl + 25.00% imidacloprid	Chemtura	4.00 oz
NipsIt INSIDE + Rancona Xtra	47.8% clothianidin + 1.02% Ipconazole + 1.65% metalaxyl	Valent	1.28 fl oz + 0.50 fl oz
Seed Shield Soybean	1.70% mefenoxam + 1.12% fludioxonil + 0.90% azoxystrobin + 22.60% thiamethoxam	Helena	3.00 fl oz
Senator 600 FS	48.77% imidacloprid	Nufarm	1.60-3.20 fl oz
Warden CZ	21.50% thiamethoxam + 3.21% mefenoxam + 1.07% fludioxonil	Winfield	3.20 fl oz

Table 17: Selected Brands, Active Ingredients, Company, and Labeled Use Rates for Nematicides and Nematicide/Insecticide/Fungicide Combinations for Seed Treatment in Soybeans in the United States, 2016

Brand	Active ingredient	Supplier	Use rates per 100 lb
Avicta Complete Beans	22.2% abamectin + 11.1% thiamethoxam + 1.87% mefenoxam + 0.55% fludioxonil	Syngenta	6.20 fl oz
Poncho Votivo	40.3% clothianidin + 8.1% <i>Bacillus firmus</i> 1-1582	Bayer	0.13 mg ai/seed

There are fifteen different seedling diseases which affect cotton, but the main ones mentioned by respondents were *Rhizoctonia solani*, *Pythium* spp., *Fusarium* spp., and Black Rot *Thielaviopsis basicola*. Descriptions of the first three pathogens have already been included in other crop segments, so only brief details of other pathogens causing crop losses in cotton are given below.

Rhizoctonia and Pythium were widely listed as the primary pathogens, but Fusarium and Thielaviopsis were also important. However, most soils contain a complex of pathogens, and climatic conditions, particularly temperature and rainfall, largely dictate which pathogens are going to affect seedling development. The new SDHI (succinate dehydrogenase inhibitor) class of fungicides offer enhanced control of seed and seedling diseases caused by *Rhizoctonia*.

Black root rot (*Thielaviopsis basicola*) is reported as causing seedling disease loss in some states particularly Texas, Arkansas, Alabama, and to a lesser extent, Arizona. The roots of the attacked plants turn black, but do not rot. If there are other fungal pathogens, there may be actual root rot and death. It has been shown that there is an interaction between *Thielaviopsis* and root knot nematodes, so that root symptoms may persist throughout the season and the maturity of infected plants is delayed.

Seed treatment may be effective in controlling *Thielaviopsis* under low disease pressure, with active ingredients, such as triadimenol. Myclobutanil has also been shown to be effective in reducing *Thielaviopsis* injury.

Cotton (Texas) Root Rot (*Phymatotrichum omnivorum*) symptoms appear in early summer and severely infected plants will die. The fungus lives deep in the soil, infects cotton roots so that the rest of the plant may wilt and die. This disease occurs throughout the Southwest and affects a wide range of plants. Cotton plant losses may be as high as 50% under high rainfall conditions, which favor spread and development of the disease.

No chemical treatment has been found to be effective, so growers have to rely on cultural approaches for control.

Verticillium Wilt (*Verticillium albo-atrum*) is present in soils, but is not transmitted by seed, and tends to be more prevalent on heavier soils, in periods of cool and wet weather. Resistant varieties need to be used. Chemical seed treatments have not been shown to be effective.

Cotton fungicides

A wide range of products are labeled for seed treatment in cotton. Bayer has Evergol Prime labeled for seed treatment in cotton for the control of seed rot and damping-off caused by *Rhizoctonia solani*.

The new broad-spectrum, pyrazole carboxamide fungicide, fluxapyroxad, developed by BASF, is formulated as an emulsifiable concentrate (EC) and marketed by Monsanto as Acceleron DX-612 for cotton seed treatment.

BASF's Headline pyraclostrobin, Syngenta's Quadris azoxystrobin, and Uniform's azoxystrobin and mefenoxam are labeled for in-furrow use to manage/control Pythium and Rhizoctonia. Bayer's Reason fenamidone and Syngenta's Ridomil Gold GR mefenoxam and Ridomil Gold PC GR PCNB and mefenoxam are labeled for Pythium seed rots and seedling diseases for in-furrow treatment at planting.

Cotton nematodes

There are three groups of nematodes: root knot (*Meloidogyne spp.*), reniform (*Rotylenchus reniformis*), and other nematode genera.

Root knot nematodes (*Meloidogyne spp.*) attack a wide range of crop plants and cause stunting and death of plants in severe cases. Light soils are particularly favorable for root knot nematode development.

Root-knot nematodes infest approximately 40% of the cotton acreage in the Southern High Plains of Texas, and if not managed, can reduce yields by an average of 26%.

Control is achieved by crop rotation with non-susceptible hosts, such as small grains and sorghum, fumigation with Telone if nematode numbers are high, and the use of seed treatment, using either Aeris, Avicta, or Votivo for low to moderate infestations.

The development of nematode tolerant or resistant varieties of cotton appears to be an important objective in the breeding programs of Monsanto, Bayer, and Dow, thus providing growers with a valuable management option.

Table 18: Brands, Active Ingredients, Company, and Product Use Rates for Selected Fungicide Seed Treatments in Cotton in the United States, 2016

Brand	Active ingredients, %	Company	Use rates fl oz per 100 lb
Acceleron DT-510	22.3% myclobutanil	Monsanto	1.250-4.000
Acceleron DX-109	18.40% pyraclostrobin	Monsanto	1.500-3.000
Acceleron DX-612	28.7% fluxapyroxad	Monsanto	0.470-0.640
Acceleron DX-709	22% trifloxystrobin	Monsanto	0.320-0.640
Allegiance – FL, Acceleron DX-309	28.35% metalaxyl	Bayer, Chemtura	0.750-1.500
Apron XL	33.30% mefenoxam	Syngenta	0.320-0.630
Baytan 30	30.00% triadimenol	Bayer	0.250-3.000
Catapult XL	30.00% chloroneb 1.95% mefenoxam	Agrisolutions	11.750
Coronet	Boscalid + pyraclostrobin	BASF	-
Dividend Extreme	7.73% difenoconazole 1.93% mefenoxam	Syngenta	2.000-5.800
Dynasty CST, Trio eXtra	6.64% azoxystrobin + 1.11% fludioxonil + 3.32% mefenoxam	Syngenta, Loveland	3.100-3.950 0.026 mg/seed
Evergol Prime	22.7% penflufen	Bayer	0.640 fl
Kodiak HB	0.30% <i>Bacillus subtilis</i>	Chemtura	4.000-8.000 oz
Maxim 4FS	40.3% fludioxonil	Syngenta	0.080-0.160
Nu-Flow M-HF	25.0% myclobutanil	Wilbur-Ellis	1.250-4.000
Nusan 30 EC	TCMTB	Wilbur-Ellis	1.250-5.000
Prevail	15.00% carboxin + 3.12% metalaxyl + 15% PCNB	Chemtura	8.000-16.000 oz
Rizo lex	42.00% tolclofos-methyl	Valent	1.500
Sebring 480 FS	44.08% metalaxyl	Nufarm	0.500-1.000
Seed Shield	5.24% azoxystrobin + 0.87% fludioxonil 02.62% mefenoxam 0.35% difenoconazole	Helena	0.023 mg ai/seed 4 oz/100 lbs
Spera 240FS	22.37% myclobutanil	Nufarm	2.250
System 3 Seed Treatment	16.67% PCNB + 4.25% metalaxyl 0.10% <i>Bacillus subtilis</i>	Helena	2.000 oz/100 lb
Trilex Flowable	22.00% trifloxystrobin	Bayer	0.32-0.64
Trilex Advanced	8.55% trifloxystrobin 4.27% triadimenol 12.82% metalaxyl	Bayer	1.600
Vitavax	34.0% carboxin	Chemtura	4.000-8.000
Vortex	40.7% ipconazole	Bayer	0.051-0.085

At present, there seems to be a yield disadvantage with these root knot resistant varieties so that growers must decide if the nematode pressure is sufficiently high to overcome the yield penalty. Since there is activity by the three major seed companies to develop cotton varieties, it must be assumed that later varieties are more likely to have comparable yields, so that in future years resistant varieties will offer a very real option for nematode control.

Reniform nematodes (*Rotylenchus reniformis*) has been expanding in the Mid-South and have become increasingly prevalent. Early feeding on the roots can cause seedling loss, and a reduction in plant stand, and weakened plants, which will not yield optimally. Control of reniform nematodes is the same as for root knot nematode.

Products labeled for nematode control are usually also combined with a neonicotinoid for insect control, so the list of currently labeled products is included in the Insects section.

Cotton insects

Insects affect the developing seedling, emerged plant, and all stages of subsequent growth. Early insect pests, such as thrips and aphids, cause significant damage to emerging cotton seedlings. Cotton plants are most vulnerable to thrips, which damage up to four to five leaves. Respondents indicated that thrips were the major insect pest in the Atlantic states and that up to 95% of cotton seed was treated with insecticide.

Increasingly, growers have been using insecticide seed treatment, either as a special order or when imidacloprid or thiamethoxam are included in the base seed treatment.

Cotton insecticides

A variety of insecticides and nematicides are used in cotton. *Bacillus firmus* is combined with clothianidin and marketed as Poncho Votivo.

Table 19: Brands, Active Ingredients, Company, and Product Use Rates for Selected Insecticide, Insecticide/fungicide and Nematicide Seed Treatments in Cotton in the United States, 2016

Brand	Active ingredients, %	Company	Use rate per 100lb
Acceleron INT-210	12.4% abamectin + 28.1% thiamethoxam	Monsanto	As per abamectin and thiamethoxam
Acceleron IX-409	48.7% imidacloprid	Monsanto	0.375 mg ai seed
Acceleron Insecticide Seed Treatment	48.7% imidacloprid 18.4% pyraclostrobin	Monsanto	16.000-20.000 oz + 1.500-3.000 oz/100 lb seed
Acceleron INT-710	24.0% thiodicarb + 24.0% imidacloprid	Monsanto	25.600 fl oz
Aeris	24.0% thiodicarb + 24.0% imidacloprid	Bayer	0.375 mg ai/seed of each active ingredient, 25.600 fl oz/acre
Avicta Duo Cotton	12.4% abamectin + 28.1% thiamethoxam	Syngenta	0.150 mg ai abamectin + 0.340 mg ai thiamethoxam per seed
Cruiser 5FS	47.6% thiamethoxam	Syngenta	0.300–0.375 mg ai/seed
Imidacloprid	48.7% imidacloprid	Several	0.375 mg ai/seed or 12.80 fl oz
Gaucho 600	48.7% imidacloprid	Bayer	0.375 mg ai/seed
Lorsban 30 Flowable	30.0% chlorpyrifos	Bayer	0.100–5.500 fl oz
Orthene 97	97.4% acephate	Amvac	6.400 oz
Poncho Votivo	40.3% clothianidin + 8.1% Bacillus firmus I-1582	Bayer	2.400 fl oz/100,000 seeds

U.S. SEED TREATMENT

The seed treatment market has become one of the most rapidly growing crop protection markets in the United States and globally. This growth has been largely fueled by genetically modified traits significantly increasing the value of protecting the more valuable seed and developing seedling. However, the increased range of highly effective seed treatment products for fungal, insect and nematode control has revolutionized this market. The availability of neonicotinoid insecticides has also permitted broader spectrum insect control with no longer any need to apply insecticide granules due also to insect resistance traits. The higher value of the insecticides has resulted in insecticides now becoming the most valuable segment.

Definition of seed treatment biopesticides in this report

There are many companies that have been developing products that claim increased yields because of either capability to fix atmospheric nitrogen or phosphate and the colonization and/or stimulation of roots. These companies point to field trials and claim yield increases of varying amounts in corn, soybeans and wheat. The products are usually recommended for treatment of the seed or at planting.

Examples include ProfitProAg's product, Soil-Biology Boost, which consists of several organisms, including three species of *Glomus*, *Azotobacter chroococcum*, and mycorrhizal fungi. This product also colonizes roots and boosts the biology in the rhizosphere. TerraMax's MICROAZ-IF Liquid contains an *Azospirillum* inoculant, and has been shown in trials to increase corn yields by 6.2 bushels per acre. Another Terramax product, Tazo-ST Liquid, is also based on *Azospirillum lipoforum* and *A. brasiliense*, which brings roots and bacteria together, to "create a dynamic interaction and the bacteria start fixing nitrogen. The bacteria also exude compounds that stimulate root growth."

However, since they do make claims for increases in yield, they compete with biopesticides with more defined activity. It is estimated that there are some 400 products being marketed as growth promoters and yield enhancers, so that producers have been having difficulty discriminating between "snake oils" and products with defined and stable formulations, which have been field tested under varied locations over several years and gained solid scientific backing.

This report includes selected microbial seed treatment products which have both defined pesticidal activity and those that protect the root system and improve plant health. Rhizobial inoculants are included for their capacity to fix nitrogen and take up phosphate for use by the plant. These products are frequently combined with biopesticides.

The huge acreages of field crops have meant that they have become the target for an ever-expanding portfolio of products from many companies.

Cultural practices have been changing and this increases the need and value of seed treatment. Earlier planting of corn has meant that conditions may favor pathogens. The wider adoption of no-till may lead to cooler and moister soil, which can delay emergence and exacerbate soil pathogen activity.

Seed companies have also been competing in providing seed treatments that provide the most comprehensive protection from soil pathogens and insects and early insect attack.

Factors affecting the market

There are many companies that have been developing products that are based on microbes that claim increased yields because of either capability to fix atmospheric nitrogen or the colonization and stimulation of roots. These companies point to field trials and claim yield increases of varying amounts in corn, soybeans, and wheat. These products are usually recommended for treatment of the seed or at planting, but they are not biopesticides.

CROPS

Corn

Corn is the largest seed treatment market with all the seed treated by the supplying corn seed companies. Corn seed companies actively discourage downstream seed treatment. Seed treatment packages are upgraded each year to include the newest products and to extend the spectrum of control. Products to control nematodes have been the recent successful entry.

Soybeans

In contrast to corn, soybeans are more commonly treated at the local level with the products best suited to the region and season. Soybean seed has been increasingly receiving inoculants and it is estimated that at least 36 million acres are treated. Inoculants are not biopesticides as they do not have any pesticidal activity.

In addition to rhizobia inoculants a range of biological products are recommended for seed treatment of soybeans. Since a high proportion of the seed treatment is applied at the local level, it is feasible for producers to request the application of a biological product that has been found to improve plant stand and health.

This report estimates that microbials are used on 22% of soybean acres with current sales of \$25.5 million, with products such as Trident, Excalibur, Yield Shield, and many others, including Novozymes Optimize inoculant plus. Yield Shield protects from Rhizoctonia and Fusarium and also colonizes roots and activates the plant's host resistance system.

Cotton

Cotton seed also gets a base seed treatment applied by the seed company often through their local distributor. However, growers frequently request an overtreatment or particular product combination to control nematodes or extend pathogen and insect control.

It is estimated that Poncho Votivo seed treatment was applied to cotton seed planted on 204,000 acres for a value of \$2.24 million. Apart from Votivo there was not any biological included in the base or optional seed treatments provided by the seed companies according to our respondents.

The major seed treatment market is in field crops: corn, soybeans, cotton, wheat, and canola. The seed of alfalfa, canola, rice, sorghum, and sugar beet, and sunflowers is treated by the seed companies with appropriate products. Some of the rice and sorghum is treated by the farmer. Microbials may have been used on the local level, but use is not included here.

Wheat

Wheat is grown in a very wide range of different environments so that soil pathogens and attacks from early foliar diseases and insect pests vary hugely from the arid conditions of the Southwest to the more humid conditions in the northern states. Since seed is often farm saved bin-run, treatment is either on-farm or by the local supplier when purchasing new seeds.

Respondents were unable to point to the use on a significant commercial scale of any biological seed treatment products. Trials in the Pacific Northwest had not shown any of the products tested so far to be effective. In Montana, the dry conditions were considered the reason why biologicals have not been shown to be of any value. One of the respondents in Oklahoma was not aware of any use of biologicals. In North Dakota, it was reported that the respondent had not seen any biological product that could compete with a chemical one.

Potato

Potato seed pieces are very susceptible to a range of soil pathogens and nematodes, so treatment ensures that the developing shoots and roots can develop normally.

Respondents were asked about the use of biologicals, but were not aware of any major commercial use currently. Comments included, “nobody can get them to work,” and “they have been evaluated and nothing stands out.”

There were two biological fungicides which were found to have a specific seed treatment recommendation -*Trichoderma harzianum* with one brand, T-22 HC, for both forms of *Rhizoctonia*, and as many as five brands of either *Streptomyces griseoviridis* or *Streptomyces* sulfate to control bacterial soft rot and blackleg.

Rice

Respondents were not aware of any widespread use of any biopesticides or biological products in rice. The anaerobic condition in a flooded rice field was considered the major reason why a biological would not be likely to work.

USE OF BIOLOGICAL PRODUCTS FOR SEED TREATMENT

There are three broad but often interlinked groups of biological products that are used for seed treatment. The difference is relatively clear between rhizobia and biopesticides, but this report attempts to distinguish between microbial products that make claims of controlling certain pathogens and those which claim pathogen control and plant health and growth promotion properties.

- Products suppressing or controlling pathogens and nematodes;
- Rhizobia which enhance nitrogen nutrition mainly in legumes or phosphate in a range of crops;
- Bacteria which enhance plant vigor and health.

Products suppressing or controlling pathogens and nematodes

There are a number of major biopesticides which are labeled for seed treatment in crops. Several of these products also contribute to plant health.

Table 20: Product Suppressing or Controlling Pathogens and Nematodes in the United States, 2016

Active Ingredient	Trade name(s)	Activity	Company
<i>B. subtilis</i> MBI 600	Integral	Soil pathogens	Becker Underwood (BASF)
<i>Pasteuria nishizawae</i>	Clariva	Nematodes +	Syngenta
<i>Bacillus firmus</i>	Votivo	Nematodes +	Bayer
<i>Bacillus pumilus</i> GB 34	Yield Shield	Soil fungal pathogens	Bayer
<i>Bacillus subtilis</i>	Kodiak HB GB 03	Various	Bayer
<i>Bacillus subtilis</i>	HiStick N/T, Vault Hp + Integral	Various	Becker Underwood (BASF)
<i>Streptomyces griseoviridis</i>	Mycostop	Soil Pathogens	Verdera
<i>Streptomyces lydicus</i>	ActinoGrow	Wide range of soil pathogens	Natural Industries Inc.
<i>Trichoderma harzianum</i>	T22 HC	Soil pathogens	BioWorks

Bayer acquired the Israeli Minrav company AgroGreen, and this included BioNem *Bacillus firmus* (trademarked Votivo by Bayer), which has been widely used for seed treatment in corn, cotton, and other crops. It is used in conjunction with clothianidin and fungicides to reduce nematode populations and root infestations in the soil, while stimulating increased yields.

Bayer has been extremely successful at combining its Votivo *Bacillus firmus* I-1582 with its Poncho clothianidin neonicotinoid insecticide. This combination has been made available to Monsanto and DuPont Pioneer for treatment of their corn.

Poncho Votivo is currently labelled in corn, cotton, sorghum, soybeans and sugar beet. Votivo (*Bacillus firmus* I-1582) is only marketed in conjunction with Poncho clothianidin, and when applied to seeds it protects the seed and seedling against certain early season insects and provides early season protection from listed plant pathogenic nematodes that attack the root system. The label states that the dual protection results in an improvement in plant vigor, which often results in more uniform plants and greater yields.

Bacterial products colonize the developing root system and suppress plant pathogenic fungal pathogens. For example, Bayer's Yield Shield contains *Bacillus pumilus* GB 34 which colonizes the developing root system and provides protection against disease organisms such as *Rhizoctonia* and *Fusarium*. "Through a mode of action in which the plant's own host resistance is activated, biological protection is achieved which frequently results in improved plant stand, plant health and yield."

Bayer's Votivo, *Bacillus firmus* I-1582 is described as being "different from any nematode product on the market. Votivo bacteria are known as "root colonizing" bacteria. Plant Growth Promoting Rhizobacteria (PGPR) work by enhancing a plant's rhizosphere, or the area immediately surrounding plant roots, and are responsible for creating conditions favorable to the plant's growth. Votivo contains a naturally occurring soil bacteria, or rhizobacteria, that live and grow with the plant's root system. The bacteria multiply exponentially creating a film that becomes a living barrier that occupies space and limits the number of receptor sites which could otherwise be occupied by plant pathogens such as nematodes."

Clariva consists of spores of *Pasteuria nishizawae* and is applied to soybean seed for the control of Soybean Cyst Nematode (*Heterodera glycines*).

Rhizobia

Rhizobia are not included in this report, but they may be mixed with pesticidal biological materials, and those products are included. Kline tried to separate the value of the biopesticide in the mixture, and the rhizobia sector is described here for information purposes, to put the biopesticidal component in perspective.

Rhizobia are estimated to be responsible for biological nitrogen fixation, and contribute between 49% and 67% of nitrogen needs in soybeans. The rhizobia are highly specific, and *Bradyrhizobium japonicum* is specific to soybeans, and will not fix nitrogen in any other legume species. In field soil where soybeans have never been grown, producers are advised to treat their seed with an appropriate product, so that adequate nodulation can take place. In Michigan, on new ground where soybeans had not been planted, as much as a 45% yield increase has resulted from inoculating soybean seed.

One of the respondents estimated that 60% of soybean producers, particularly in the Southern states, were treating their soybean seed with rhizobia. This report concludes that overall an estimated 47% of soybean seed is being treated with commercial inoculants.

The current value of the inoculant market is estimated at \$81.6 million. The major products include Optimize, Hi-Stick, Nit Fix, and Cell-Teck. Average grower cost is \$2.25 per acre.

Rhizobia are used primarily in leguminous crops and may be combined with biological products. Various products are currently available.

Table 21: Selected Brands, Active Ingredients, Company, and Labeled Use Rates for Inoculants for Seed Treatment in Soybeans in the United States, 2016

Brand	Active ingredient	Supplier	Formulation use rate
Vault HP	Three way includes rhizobia, growth enhancers, and biofungicides	Becker Underwood	2.0 fl. oz
Vault NP	USDA TA-11 Nod + rhizobia	Becker Underwood	Concentrated liquid
Vault SP	USDA TA-11 Nod + rhizobia	Becker Underwood	Peat-based carrier
Excalibre	Rhizobia + iGET Technology Trichoderma +	ABM	0.05 oz/140,000 seeds
Graph-EX SA	Rhizobia + iGET Technology	ABM	Talc/graphite carrier
Optimize	Rhizobia + LCO Promoted Technology	Novozymes	1.4 fl. oz/140,000 seeds
America's Best Inoculant	Rhizobia	ABM	2.1 fl. oz/140,000 seeds
HiStick NT	Rhizobia + <i>Bacillus pumilus</i>	Becker Underwood	77 ml/27.2 kg seed
Trident	Rhizobia +	Precision Laboratories	1.6 fl. oz/100 lb
Launcher	Rhizobia (2)	Precision Laboratories	8.35 lb/gallon

BACTERIA ENHANCING GROWTH THAT IS INCLUDED IN THE BIOPESTICIDE REPORT

The active ingredient in JumpStart, the naturally occurring soil fungus, *Penicillium bilaii*, grows on plant roots and makes less available residual soil phosphate immediately available for crop use.

Several seed treatments include both rhizobia for nitrogen nutrition and a microbial pesticide, as in ABM's SabrEx seed treatment, which includes Trichoderma species to provide induced gene expression triggers to aid in plant health.

There are certain bacteria that enhance plant vigor and health. This category consists of bacteria whose primary mode of action is to colonize and protect the roots. They have been shown to increase plant vigor and health, and so protect plants from soil pathogens.

ABM's ExCalibur GOLD is a Trichoderma-based product that contains patent-pending strains utilizing ABM's iGET technology. This product makes no claims for specific pathogen control. It helps the plant produce a much larger root system; develop resistance to plant stresses, such as disease and drought; and increase nutrient uptake, so that the plant will better utilize the nutrients readily available to create greater potential for a better crop.

BioWorks T22 HC Biological Fungicide is also based on a *Trichoderma* (*T. harzianum* strain Rifai T-22 HC) and provides protection against plant root pathogens, such as *Pythium*, *Rhizoctonia*, *Fusarium*, *Cylindrocladium* and *Thielaviopsis*. However, the label does not specifically mention its benefit of increasing plant health and vigor.

FACTORS AFFECTING THE SEED TREATMENT MARKET

The chemical seed treatment products have become increasingly effective and are achieving high levels of control of most of the pathogens and insects. Companies such as Syngenta and Bayer are focusing specifically on seed treatment so that their products meet current market needs, where standards are high.

Pressure continues to reduce overall chemical use, particularly in Europe. Even though seed treatment requires only a fraction of the product required for soil or foliar treatment, the market and regulators are likely to welcome any substitution of a chemical with a biopesticide.

Several of the large acreage crops are treated by the seed producer in large volume seed treatment plants. However, there has also been developing distribution chains with increasingly sophisticated treatment equipment, so as to be able to treat seed with appropriate products in order to meet special local needs. Each crop has different seed treatment patterns which must be understood.

Fungicides are usually the basis of any seed treatment, so compatibility and shelf life of any chemical + biological combination must be determined. Development trials under varying conditions will be critical to fully understand the correct product performance.

OPPORTUNITIES FOR BIOPESTICIDES FOR USE AS SEED TREATMENTS

Interest in reducing chemical use provides a definite market opportunity to provide performance that is comparable.

While there is still insufficient understanding of all the complex and delicate interactions occurring in the soil, it is more likely that a microbial product will be less likely to interfere with the mycorrhizal root interaction.

Several soil diseases remain difficult to control so that any product able to colonize roots and protect them would be highly desirable. Take-all in wheat and Sudden Death Syndrome in soybeans would be good examples of this.

FRUIT AND NUTS

The primary fruit and nut crops using biopesticides in the United States are apples, grapes, strawberries, and treenuts, with citrus considered an opportunity. Fruit is grown in virtually every state, with citrus production predominating in the South and apples in the northern states. Strawberries are primarily grown in California, but also in other states, particularly Florida. Insect pests and diseases have the chance to get well -established in perennial orchards, groves, and fields where fruit is grown.

Disease is heavily influenced by climate so that the drier conditions in Washington provide less favorable conditions. In other regions, regular sprays throughout the season are necessary. Insect pests are also ubiquitous, but there are regional variations in severity.

The implementation of IPM has been widespread as growers have been attempting to utilize natural predators to provide control of several insect species. Interest in biopesticides that are soft on natural predators is strong.

ACREAGE AND FARM GATE VALUE OF FRUIT AND NUTS

There is a wide range of fruit and nuts produced in the United States. The USDA figures for total crop values clearly indicate the clear dominance of California, followed far back by Washington and Florida.

The value of fruit and nuts to California at the farm gate level represents 66.2% of the national total. The state produces virtually all the nuts grown in the country, particularly almonds and walnuts. Around 87.3% of the fruit and nuts are produced in three states. Citrus is the major fruit crop in Florida and apples in Washington. The remaining 12.7% is spread across the rest of the country.

Table 22: Total Value of Production of Fruit and Nuts in the United States, 2012

State	\$ Million	%
California	17,108	66.2
Washington	3,357	13.0
Florida	2,093	8.1
Oregon	601	2.3
New York	323	1.2
Georgia	321	1.2
Wisconsin	251	1.0
Michigan	208	0.8
Pennsylvania	187	0.7
New Jersey	179	0.7
Texas	160	0.6
North Carolina	121	0.5
All other	943	3.6
Total	25,852	100.0

2012 is the latest data available.

By far the largest fruits and nuts produced in the United States are grapes, almonds, strawberries, apples, pears and walnuts. California is a major producer of all of these crops owing to its unique environment.

GRAPES

Grapes are produced widely in California, both wine (568,000 acres), and table and raisin grapes (297,000 acres). The number of acres of wine grapes treated with pesticides has varied from 7.1 million acres in 2008 to 9.7 million in 2011 with 9.2 million treated in 2016. According to the Department of Pesticide Regulation, changes in pesticide use on wine grapes are influenced by a number of factors, including weather, topography, pest pressure, evolution of resistance, competition from newer pesticide products, commodity prices, application restrictions, efforts by growers to reduce costs, and increased emphasis on sustainable farming.

The next section largely refers to California, as the state represents the largest acreage of grapes.

Insect control

There are several insect pests, including omnivorous leaf roller, vine mealybug, western grape leafhopper, Virginia creeper leafhopper, and European grapevine moth. New insect pests include European Grapevine Moth which has been quarantined in some districts. A wide range of pesticides are listed for control including some biopesticides. Imidacloprid has been the most widely used insecticide, but recently, its use has been declining slightly, while Abamectin use has been increasing steadily. Spirotetramat is effective on mealy bugs, and its sales have also been increasing. Oil use had been growing for winter use, as surfactants with fungicides, and to eradicate powdery mildew, as well as suppressing mites and some other insects. Use of *Bacillus thuringiensis* declined 34% in 2012. Insect predators can also provide some control, so that understanding of primary and secondary insect pests is important, to ensure that populations of predators can be maintained.

Disease control

There are many diseases which affect grapevines including powdery mildew, downy mildew, botrytis, Phomopsis leaf and cane spot, and Eutypa dieback. Downy mildew tends to be less serious, largely due to dry springs and summer. Powdery mildew is widespread, and a wide spectrum of products are registered for use.

During the past few years copper has been the leading fungicide with over 0.3 million acres treated with steadily increasing acreage. The second tier of products—trifloxystrobin, pyraclostrobin/boscalid and myclobutanil—has been steady. There are indications that growers are aware of the need to switch fungicides with different modes of action to delay the development of resistance. The use of difenoconazole and metrafenone has increased threefold at the expense of products that have been around longer, such as cyprodinil.

The current option for nematode control involves use of an appropriate product prior to planting, but there is limited, if any, effective capability for controlling nematodes in mature crops.

Table 23: Bearing Acreage, Yield, Production, Price per Tonne, and Value for Grape production in the Five Major States in the United States, 2016

State	Bearing acreage	Yield per acre, tonnes	Production, thousand tonnes	Price per tonne, USD	Value, USD million
California wine	568,000	6.62	3,705	679.00	2,515
Table	113,000	10.10	1,135	1,530.00	1,791
Raisin	184,000	10.90	2,007	347.00	696
Sub-Total	865,000	8.00	6,847	724.00	5,002
Washington	70,000	5.89	417	780.00	296
New York	37,000	3.92	145	390.00	57
Oregon	19,000	3.42	65	2,270.00	147
Pennsylvania	13,000	5.92	106	319.00	24
All other	32,700	-	97	-	83.5
TOTAL	1,036.7	7.51	7,677	724.00	5,610.0

SOURCE: USDA NASS, July 2016.

ALMONDS

Almonds are grown exclusively in California and the state is now the largest almond producer in the world. Almond production has been growing at a consistent rate of 20,000 to 30,000 acres per year. This growth rate has been impacted by the droughts in California. Almonds are heavy water users, and it is unlikely that this grow rate will continue.

Table 24: Bearing Acres, Yield, Production, and Total Value for Almonds in California, 2009 to 2016

Year	Bearing acres	Yield per acre, lb shelled	Production, Million lb	Price, USD/lb	Value, USD million
2009	720,000	1,960	1,410	1.65	2,293.5
2010	740,000	2,220	1,640	1.79	2,903.4
2011	750,000	2,600	1,950	1.79	3,463.7
2012	820,000	2,020	1,655	2.58	4,816.8
2013	840,000	2,060	1,733	2.90	5,768.1
2014	870,000	1783	1,548	4.00	7,388
2015	890,000	1830	1,629	2.84	5,325
2016	900,000	2220	2,000	3.11	6,234

USDA NASS: Non-citrus Fruits and Nuts Preliminary Summary, July 2016.

Citrus production is dominated by two states: California and Florida. California has the higher value, while Florida has the higher acreage owing to the relatively inexpensive orange juice market.

Table 25: Bearing Acreage, Production for Fresh and Processed Citrus, and Value for Major States in the United States, 2014 to 2015

State	Bearing acreage	Thousand tons		USD Million
		Fresh production	Processed production	
California	271,800	2,869	791	1,917.6
Florida	459,100	556	4,487	1,341.9
Arizona	9,500	56	31	63.4
Texas	24,500	168	64	55.1
Total	764,900	3,649	5,373	3,378.0

SOURCE: USDA NASS September, 2015.

STRAWBERRIES

California produced 2.7 billion lb of strawberries in 2016, which represents 90% of the country's total fresh and frozen strawberries production. The unique coastal environment provides moderate temperatures all year round, so that strawberries can be grown over a long season, from San Diego to Monterey Bay. In Florida, strawberries are largely produced in the winter to supply the out-of-normal-season market.

Biopesticides are quite widely used in strawberries, particularly insecticides. The list of biopesticides includes those used on more than 200 acres. Two products that can be used as reference are Abamectin with 57,224 acres and sulfur with 208,067 acres.

A Strawberry Advisory System has been developed in Florida which could significantly reduce the number of sprays for anthracnose and botrytis. The system uses temperature and leaf wetness to time fungicide sprays and communicate the information rapidly by smart phone. This would be the perfect system to integrate the use of biopesticides.

Table 26: Acreage of Biopesticides in California Strawberries, 2012

Active substance	Product name	Acres treated
<i>B.t. kurstaki</i> ABTS 351	Dipel, Biobit, Foray	26,684
Pyrethrins	Many	20,730
<i>B.t. kurstaki</i> SA-12	Thuricide, Javelin, Deliver, others	19,676
<i>Bacillus thuringiensis aizawi</i>	Many	19,362
<i>B. subtilis</i> QST 713	Serenade	10,259
<i>Reynoutria sachalinensis</i>	Regalia, Regalia Maxx, Milsana	8,979
<i>Bacillus pumilus</i> QST 280	Sonata, Ballas Plus	2,681
<i>Streptomyces lydicus</i> WYEC 108	ActinoGrow	1,386

SOURCE: Commodity Database California Department of Pesticide Registration, 2012.

Table 27: Planted Acres, Yield, Production, Price per Cwt., and Value for Strawberries, in the United States, 2016

State	Planted acres	Yield, cwt./acre	Production, 1,000 cwt.	Price per cwt.	USD
California	40,500	690	27,909	66.5	1,855.0
Florida	11,000	225	2442	119	290.0
North Carolina	1,200	130	143	164	23.4
Oregon	1,500	111	155	86	13.2
Washington	790	111	155	122	7.8
New York	960	36	29	254	7.4
Pennsylvania	650	57	34	213	7.2
All other	2,210	-	221	-	18.4
Total	58,810	532	31,088	71.9	2,222

SOURCE: USDA, NASS, July 2016.

APPLES

Apples are grown primarily in the West, but also in the Northeast and to a much lesser extent in the Southeast. They are attacked by a wider range of fungal pathogens and insect pests than any other crop and normally require multiple sprays to ensure both optimal yields and quality. Apples are considered to be amongst the most difficult crops to grow organically particularly in climatic areas which favor scab and other diseases.

Disease control is certainly a severe challenge, but there is an increasing body of experience to indicate that the yield gap can be minimal between a managed organic and conventionally managed orchard, particularly when insect control is considered. The organic system capitalizes on ecosystem services by planting resistant cultivars, managing soil fertility and preserving natural predators by careful choice of highly specific products so that natural enemies are fully utilized.

However, climate plays a major role in determining which diseases and insects are prevalent. Disease control is particularly affected by climate, meaning control measures are required.

Table 28: Diseases and Insect Pests of Apples in the United States by Region, 2015

Region	Major diseases	Key insects
West	Some scab	Codling moth
	Fire blight	Apple maggot
	Powdery mildew	Catfacing bugs
		Oriental fruit moth
Northeast	Scab	Codling moth
	Fire blight	Plum curculio
	Mildew	Trunk borers
	Cedar apple rust	European sawfly
	Sooty blotch	Apple maggot
	Summer rots	Catfacing bugs including Marmorated stink bugs
Southeast	Scab	Plum curculio
	Fire blight	Codling moth
	Cedar apple rust	Oriental fruit moth
	Sooty blotch	Trunk borers
	Summer rots (severe)	Catfacing bugs
SOURCE: ATTRA (National Sustainable Agriculture Information Service).		

According to the USDA in a 2011 report, 96% of producers scout for insects and diseases, with the scouting carried out either by the farm operator, family members, farm supply agent, or an independent consultant. A total of 1.4 million lb of insecticides and 5.5 million lb of fungicides were applied to apples. Kaolin was the highest volume insecticide at 27%, followed by carbaryl, petroleum distillate, phosmet, and azinphos-methyl. Calcium polysulfide was the highest volume fungicide, followed by captan, sulfur, mancozeb, smaller quantities of copper formulations, and metiram and a wide range of other fungicides.

Major insects and diseases of apples

Codling moth (CM) *Laspeyresia pomonella*: Codling moth is widely considered the most serious insect pest for apples. Apple is the preferred host, but CM also feeds on other top fruit, including pear, peach, plum, and cherries. Since moths can emerge over a period, in spring treatment should be carried out before the larvae can penetrate the fruit. Monitoring moth flight has been found to be critical, and pheromones are widely used. Biological agents also play a critical role in parasitizing the eggs. Spring moth flight occurs over a long period, and pheromone traps are a valuable IPM tool for timing of sprays. There is a range of conventional insecticides labeled for Codling Moth and pheromones. Pheromone mating disruption has become very effective with new dispensing technology, which is used to treat about 90% of the apples in Washington State.

Opportunities for biopesticides in apples

IPM: It is generally acknowledged that apples represent one of the toughest crops for insect and disease control, and apples orchards can get 15 sprays per season. The crop is perennial and so a wide range of damaging insects is found in apple orchards, but many have natural predators. Consequently, integrated pest management of insect and mite pests is widely considered to be the key to successful apple production by using natural predators.

Beneficial populations must be maintained. Biopesticides usually offer highly specific control so that beneficial species are not affected.

Insect control: The adoption of mating disruption for CM control is an indication of interest in any material that provides control of a single important insect without impacting beneficial insects.

Resistance with conventional chemicals has been a problem, particularly with mites, so that alternative products, particularly biopesticides, can delay resistance and be used when resistance has started to occur.

Fireblight: Indicated in a recent survey as a real need, biopesticide products are available to control fireblight.

Table 29: Bearing Acreage, Production, Price per lb and Value for Major Tree Fruit Crops and Walnuts in the United States, 2016

Crop	State	Bearing acreage	1,000 tonnes	USD	
				Price per lb	Thousand
Apples	All	315,800	5,002	0.372	3,394.0
Pears	All	48,940	840	0.250	500.0
Peaches	All	99,790	847	0.310	606.0
Cherries	All	127,830	464	0.430	835.9
Walnuts	California	300,000	603	1.820	976.0
Total		892,360	7,756		6,311.9

SOURCE: USDA NASS, July 2016.

FACTORS AFFECTING FRUIT AND NUT PRODUCTION

Climate and weather

These are the two inter-related factors which have influenced the location and cropping of fruit and nut crops. The climate in California and availability of water for irrigation has been the reason for the large acreages of fruit and nut crops from citrus in the South, grapes in the more northern valleys, and strawberries from Ventura to San Diego and Orange counties.

Highly sophisticated marketing infrastructure

This has grown up with the industry so supermarket and food service chains can be supplied swiftly with large volumes of quality produce throughout the year. Shippers play a crucial role in being agents for growers and sourcing supplies from different geographic areas to maintain supplies to their customers. There were estimated to be 3,214 shippers in the United States in 2016, with over one-half being situated in California and Florida. The greatest volume of fruit is supplied by growers in the major production areas, but locally produced fruit plays a role in seasonal supply.

Local markets

Farmers markets have grown significantly over the last few years, together with farm stands for local producers to sell their seasonal fruit crops. It is expected that there will continue to be strong demand for locally produced food and often there is stress on either organic or sustainable production.

Food safety

The Food Safety Modernization Act is creating new standards for food safety at all levels. Even though food safety risks are low from consuming fresh produce, Good Agricultural Practices will be required to ensure high standards of safety for all fruit and produce. Traceability is gradually getting implemented, because of the Produce Traceability Initiative.

Standards

Many standards are set by the market and not the government, and verified by independent third-party verifiers, and are designed to minimize food safety risk. Roberta L. Cook in Choices 4th Quarter 2011 wrote that “Both GAPs and verification methodologies are evolving rapidly in tandem with knowledge of effective risk mitigation strategies, as well as rising expectations about acceptable risk. Social and environmental responsibility best practices and requirements are still in their infancy but there is a growing understanding that sustainability must be considered on a supply chain-wide basis.”

Regulatory

EPA is constantly reviewing pesticides and applying stricter limitations on use in terms of human, ecosystem, operator, and consumer safety. High costs of registering conventional insecticides may mean that there is a very limited choice of products. Biopesticides are much less expensive to register, and so can fill more limited insect control markets.

Bees

Bees play an important role in many fruit crops and nuts, particularly in almonds, so that growers are anxious to ensure that sprays do not affect populations adversely. Soft products and those that do not affect bees and natural predators are increasingly important.

This report provides a summary of three of the major fruit markets and indicates current use of biopesticides, according to California Department of Pesticide Regulation (DPR) data for 2016.

FRUIT MARKET OVERVIEW

The total biopesticide market on fruits and nuts is \$114 million, primarily for apples, grapes, strawberries, and tree nuts.

Table 30: Biopesticide Products Used on Fruits and Nuts with Identifiable Sales Over \$200,000 in the United States (based on interviews), 2016

Active	Product brands	Major supplier	Other suppliers
Azadirachtin	Azatin	Certis	PBI Gordon
<i>Bacillus pumilus</i> QST2808	Sonata, Ballad Plus	Bayer	AgraQuest (Bayer)
<i>Bacillus subtilis</i>	Cease	BioWorks	BioWorks
<i>Bacillus subtilis</i> & <i>amyloliquefaciens</i>	Quickroots, Rhizopro	Monsanto	TJ Technologies
<i>Bacillus subtilis</i> QST 713	Rhapsody, Serenade, Serenade Max, Serenade Soil, Cease	Bayer	AgraQuest (Bayer), BioWorks Inc
<i>Bacillus thuringiensis</i> ABTS-351	Dipel, Biobit, Foray	Valent	Valent
<i>Bacillus thuringiensis aizawai</i> GC91	Agree, Design, Florbac, Jackpot, Ketch	Certis	BioBest, Certis
<i>Bacillus thuringiensis kurstaki</i> 2348/2371	Condor	Certis	Certis
<i>Bacillus thuringiensis kurstaki</i> EG 7841	Crymax	Certis	Certis
<i>Bacillus thuringiensis kurstaki</i> SA 12	Thuricide, Javelin, Deliver, others	Certis	Certis, Koppert, others
<i>Bacillus thuringiensis sulfur</i>	Bt Sulfur Dust	Several	Several
Brandt other	Brandt other	Brandt	Brandt
Burkholderia species MBI 396	Venerate XC	Marrone	Marrone
Calcium polysulfide	Lime Sulfur	Novo Source	TKI
<i>Cydia pomonella granulovirus</i> V22	Madex HP, Carpovirusine, Cyd-X, Virosoft	Certis	Certis USA, Arysta
<i>Gliocladium virens</i> GL-21	Soilgard	Certis	Certis
Harpin protein	N-Hibit Gold Cst, Messenger, Proact, Employ	Plant Health Care	Plant Health Care: Eden Bioscience
Hydrogen dioxide/peroxyacetic acid	Green Clean, Terraclean, Zeritol	BioSafe Systems	Biosafe Systems
Kaolin clay	Surround, Snow Plus	Novo Source	TKI, Wilbur Ellis
<i>Myrothecium verrucaria</i>	Ditera	Valent	Valent
Other	Fireline 17, Mycoshield	Sipcam Advan Total	Sipcam Advan
Oxytetracycline	Fireline 17, Mycoshield	Nufarm, Maronne	Nufarm, Sipcam Advan
<i>Paeclomyces lilacinus</i> PL251	Melocon WG, Bioact, Bio-Nematon	Certis	Certis, T. Stanes

(Continued)

Table 30: Biopesticide Products Used on Fruits and Nuts with Identifiable Sales Over \$200,000 in the United States (based on interviews), 2016

Active	Product brands	Major supplier	Other suppliers
<i>Pantoea agglomerans</i> strain E325	Bloom Time Biological 3	Brandt	Brandt, Northwest Agricultural Products: Nufarm
<i>Penicillium bilani</i>	Jumpstart	Monsanto	Novozymes: Syngenta
Polyo1in D	Ph-D	Arysta	Arysta
Potassium salts	Des-X	Certis	Certis
Potassium silicate	Sil-Matri1	Certis	Certis
<i>Pseudomonas fluorescens</i> A506	Blightban, Bio-Cure-B	Nufarm	Good Bugs: Nufarm
Pyrethrins	Pyganic, Pyrellin, Pyrenone	Valent (MGK)	Webb Wright, Brandt
<i>Reynoutria sachalinensis</i>	Regalia, Regalia Maxx, Milsana	Marrone	Marrone
Rosemary and peppermint oil	Ecotec	Brandt	Brandt
Sabadilla alkaloids	Veratran D	Brandt	Brandt
Saponins	Nema-Q	Brandt	Brandt
<i>Steinernema feltiae</i>	Neema Shield	BioWorks	Bioworks
<i>Streptomycin lydicus</i> WYEC 108	Actinovate, Opportune	Monsanto	Natural Industries: Novozymes
<i>Agrobacterium radiobacter</i> strain k84	Galltrol-A, Gallex, Nogall K1026	AgBioChem	AgBioChem

Sales by classification

Of the total market of \$114 million, the leading product classification is Botanicals, with sales of \$52.0 million, or 45.6% of the total. Microbiol products are second, with a value of \$18.4 million or 16.1%. Minerals follow with sales of \$14.4 million or 12.6%, followed by pheromone with \$14.3 million, or 11.5%. Pheromones have a significant market in the fruit and nut markets they are used for mating disruption of codling moths and other lep pests. Kline's view is that the total U.S. fruit and nut pesticide market is \$1.1 billion so biopesticides account for about 10%.

Table 31: Biopesticide Sales of Fruits and Nuts in the United States by Product Class, 2016

Biopesticide classification	Representative brands	\$ Thousand	% Of total
Botanicals	Pyganic, Pyrellin, Pyrenone, Ecotec, Nema-Q, Trilogy, Neemix,	52,020	45.6
Microbiols	Quickroots, Rhizopro, Rhapsody, Serenade, Dipel, Foray, Fireline 17, Mycoshield, Condor, Crymax	18,350	16.1
Minerals	Green Clean, Surround, PH-D, Azera, Azakaranj, Lime Sulfur, N-Hibit Gold, Messenger	14,350	12.6
Pheromones	No Mate, Cidetrack	14,300	12.5
Fermentation product	Fireline, Typy, Refine	11,650	10.2
Viruses	Madex HP, carpovirusine, Cyd-X, Virosoft	2,500	2.2
Beneficial nematodes /other	Nemasys, Nemashield	800	0.7
Total		113,970	100.0

Sales by active substance

There are many active biopesticide ingredients used in the fruits and nuts market. The leading active substance in fruits and nuts is Aviglycine at \$18 million, followed by Azadirachtin and the pheromone (E, E) 8,10 dodecadien-1-ol, with sales estimated at \$6.5 million each. Pyrethrin and *Bacillus Thuringiensis* follow in third and fourth place with sales at \$6.0 million each, or 5.3.0% of the fruit and nuts segment. This is a market with many actives, and the top 10 products only account for 58.3% of sales.

Table 32: Biopesticides Sales of Fruits and Nuts in the United States by Active Substance, 2016

Active substance	Major brands	\$ Thousand	% Of total
Aviglycine	Retain	18,000	15.8
Azadirachtin	Azatin, Neemix, Trilogy, Azera, Agroneem, Azatrol, Azakaranj	6,500	5.7
(E,E) 8,10 dodecadien-1-ol	No Mate, CM Microflake	6,500	5.7
Pyrethrin	Pyganic, Pyrellin, Pyrenone	6,000	5.3
Bacillus thuringiensis	Dipel, Foray, Agree, Florbac, condor, Crymax, Thuracide, Javelin	6,000	5.3
Oxytetracycline	Fireline 17, Mycoshield	5,600	4.9
Reynoutria sachalinensis	Regalia, Milsana	4,500	3.9
Chromobacterium subsugae	Grandevo	4,500	3.9
Gibberillic acid/6-ABA	Novogib, Nofly, Ascend	3,850	3.4
Bacillus subtilis	Quickroots, Rhizpro, Rhapsody, Serenade	3,200	2.8
8,10-Dodecadien-1-ol, (8E, 10E)	Cidetrack	3,000	2.6

(Continued)

Table 32: Biopesticides Sales of Fruits and Nuts in the United States by Active Substance, 2016

Active substance	Major brands	\$ Thousand	% Of total
Carnauba wax	Heat shield	2,500	2.2
Cydia pomonella granulovirus V22	Madex HP, Carpovirusine, Cyd-X, Virosoft	2,500	2.2
Calcium Polysulfide	Lime Sulfur	2,100	1.8
Polyoxin D	PH-D	1,500	1.3
Neem Oil	Trilogy	1,000	0.9
Clove oil	Phydura	300	0.3
All other-a	-	36,420	32.0
Total		113,970	100.0

a- Includes Agrobacterium radiobacter, gliocladium virens, pseudomonas, potassium salts, potassium silicate, sabadilla alkaloids, steinemema, and many others.

Sales by supplier

Valent is the leading supplier of biopesticides to the fruits and nuts segment with sales of \$42.2 million, or 37.0% of the market segment. Marrone is the second-leading supplier with \$9.6 million, followed by Nufarm and Certis, with sales at \$8.25 million and \$6.6 million, respectively. Surprisingly, several distributors, such as Helena and Wilbur Ellis, make the list with their private label products.

Table 33: Sales of Biopesticides on Fruits and Nuts in the United States by Supplier, 2016

Supplier	Active material	\$ Thousand	% Of total
Valent	<i>Bacillus thuringiensis</i> , <i>myrothecium verrucaria</i> , Azadirachtin, pyrethrins and others	42,200	37.0
Marrone	<i>Reynoutria sachalinensis</i> , <i>Burkholderia</i> species, and other	9,600	8.4
Nufarm	Oxytetracycline, pseudomonas, streptomycin, Gibberellin, sulfur	8,250	7.2
Certis	<i>Cydia pomonella granulovirus</i> , <i>paecilomyces lilacinus</i> , <i>B. thuringiensis</i> , azadirachtin, potassium salts, <i>gliocladium virens</i> , poly-D zinc, and others	6,600	5.8
Hercon Labs	,10-Dodecadien-1-ol, (8E, 10E), (E,E) 8,10 dodecadien-1-ol	4,800	4.2
Fine Agrochemical	Refine, Falgro,	3,700	3.2
Novasource	Kaolin, Calcium polysulfide	3,400	3.0
Bayer	<i>Bacillus subtilis</i> , <i>Bacillus pumilus</i>	3,200	2.8
Arysta (Chemtura)	Polyoxin D	3,100	2.7
Loveland	Phosphoric acid, Gibberilic acid, Naphthalic acid	2,500	2.2
Wilbur Ellis	Sulfur	2,500	2.2

(Continued)

Table 33: Sales of Biopesticides on Fruits and Nuts in the United States by Supplier, 2016

Supplier	Active material	\$ Thousand	% Of total
Brandt	Rosemary, sabadilla alkaloids, saponins, <i>pantoea agglomerans</i> , iron phosphate/spinosad, and others	2,120	1.9
Helena	Phosphoric acid, potassium bicarbonate	1,100	1.0
BioWorks	Potassium bicarbonate	1,000	0.9
Sipcam Advan	Oxytetracycline, pseudomonas	600	0.5
Plant products	<i>Pseudozyma flocculisa</i>	500	0.4
Dow	Potassium oleate	100	0.1
All other		18,700	16.4
Total		113,970	100.0

OPPORTUNITIES FOR BIOPESTICIDES IN FRUIT

The strong interest in IPM for fruit production creates opportunities for products for insect and pathogen control that are specific in action and do not affect beneficial species.

Products that can be applied close to harvest and that have minimal reentry intervals will provide flexibility to fruit producers.

The list of fruit industry needs was developed by those extension and research staff interviewed.

Table 34: Priority Target for Biopesticides on Fruit in the United States, 2016

Priority	Target
1	Citrus greening
2	Spotted Wing Drosophila—all fruit
3	Marmorated stink bugs—all fruit
4	Brown rot, blossom blight and fruit rot—stone fruit

VEGETABLES (INCLUDING POTATOES)

While there is a very significant concentration in California and Florida, vegetables and potatoes are grown in every state. Larger growers enjoy the benefits of scale due to the large volume of quality produce required by the large national and regional supermarket chains and food service companies. Some of the larger producers also have farms, or contracts with farmers in other regions and climatic zones to supply regional markets. There are still many smaller producers supplying local or more regional markets, and taking advantage of local climatic, seasonal, and soil advantages.

According to the U.S. Census, over 69,000 vegetable and melon growers are active, but over 90% of the vegetable acreage is controlled by just 20% of the farms, so the concentration of larger farms is an important market factor in supplying biopesticides.

Vegetables and potatoes are grown for both the fresh and processing markets, under which processing might include freezing, canning or juicing. Product appearance and quality is critical for the fresh market but less so for processing. As a result, quality is critical for the fresh market, so that the control of insects and diseases causing damage, blemishes, and discoloration must be avoided to ensure saleable products. For the processor markets, the bar is somewhat lower, and production cost for management is higher.

ACREAGE AND VALUE OF VEGETABLES

The USDA estimates that 1.6 million acres of the 34 major vegetable crops were planted in 2015 with a production value of \$12.4 billion. California alone represents 44.3% of the acreage, and just over 58% of the total value. Florida is next with 10% of acres and 8.9% of value, followed by two southern states, Arizona and Georgia. The remaining 30% of acres was distributed across both southern and northern states.

California and Florida dominate the commercial vegetable production market. California's climate allows the production of a very wide range of vegetables during the summer and even winter season, due to the north/south length of the state. Florida is number one in the country for cucurbits—watermelon, cucumbers, and squash—and second, for tomato and bell pepper production.

Table 35: Vegetable Planted Area and Production in the United States, 2015

State	Planted acres	% Of total	Production, \$ million	% Of total
California	722,400	44.3	7,262	58.3
Florida	163,800	10.0	1,102	8.9
Arizona	113,800	7.0	1040	8.4
Georgia	96,500	5.9	470	3.8
Washington	54,600	3.3	435	3.5
New York	59,300	3.6	276	2.2
Michigan	51,200	3.1	209	1.7
Oregon	30,100	1.8	177	1.4
Pennsylvania	20,230	1.2	177	1.4
Texas	63,400	3.9	163	1.3
New Jersey	23,800	1.5	156	1.3
North Carolina	32,100	2.0	142	1.1
Ohio	31,700	1.9	135	1.1
Illinois	21,600	1.3	22	0.2
All other	145,900	8.9	685	5.5
Total	1,630,430	100.0	12,451	100.0

SOURCE: USDA NASS.

KEY TRENDS AFFECTING VEGETABLE PRODUCTION AND MARKETING

Key trends affecting the 69,100 total number of vegetable and melon farmers producing for the fresh and process markets in the United States include:

- The growth of organic produce, requiring increased record keeping;
- Food safety concerns have been growing, resulting in a higher cost structure;
- Grower shippers are emphasizing sustainable farming practices;
- There is more branding and private labeling to provide differentiation to the consumer;
- Consolidation: Just under 5,000 farms selling more than \$1 million, account for 8% of farms and 84% of total value. In California, just over 1,000 farms contribute 36% of the total U.S. vegetable sales value;
- Margin pressure at all levels of the food system.

All these trends indicate that growers are increasingly concerned about safety, demonstrable sustainability, and satisfying the requirements of shippers and supermarket chains. Margin pressure means that each cost must be carefully assessed, but satisfying trade channels will trump cost reduction in grower operations.

Scale is likely to continue to be important so that further consolidation in the chain from farm to consumer is likely to continue.

INSECTS, DISEASES, AND NEMATODES AFFECTING VEGETABLES

A very wide range of pests attack vegetables. Although there are many different vegetables, crop protection companies have been able to gain registrations across vegetable families, so that a good selection of conventional products is available to the grower.

The cost of registration has increased so that companies have had to raise market potential hurdles before committing to registering new products. Biopesticides have a clear advantage in registration costs since tolerances are not needed, and the products generally offer zero or short harvest treatment intervals.

POTATOES

Potatoes have been harvested on between 1.0 and 1.33 million acres since 2006, and the planted area appears to be leveling off at just over 1.0 million acres. In 2014, potato growers were asked to reduce their acreage because the current area was likely to produce a surplus, which would depress market prices and acreage remains at just over 1.0 million acres.

The industry is fighting hard to ensure that potatoes are maintained in school meal programs and that the health/cost benefit is understood. There are hopes that the combination of increased exports and promotion of one of the “world’s healthiest foods” will enable sales to be maintained in domestic markets. While exports of processed potatoes have been increasing, it seems unlikely that the overall U.S. acreage will expand as yields continue to increase.

The production of seed potatoes is a critical element in providing seed that meets tough standards for the presence of pathogens and viruses. Consequently, insect and disease control during seed production requires growing the crops in more secluded areas and paying extra attention to control procedures.

Potatoes are well-known for being attacked by a wide range of insects, fungal, and bacterial pathogens, as well as nematodes. While pest incidence varies significantly depending on the local climate and geographical location, diseases represent an estimated 48% of crop protection expenditure, followed by 23% and 19% for insects and weed control respectively, and 10% for seed treatment (Bayer’s assessment). There are concerns about the A2 strains of *Phytophthora*, which have developed a resistance to metalaxyl, the appearance of resistant strains of *Rhizoctonia* and *Alternaria*, and the spread of psyllids transmitting the virus that causes Zebra chip disease. Colorado Potato Beetles have been developing resistance to neonicotinoid insecticides.

Use of biopesticides in potatoes has been distinctly limited. The crop is highly costly to grow, typically \$3,700 to \$4,000/acre, and growers have learned to rely on conventional chemicals to provide the high level of protection and control that is required throughout the potato production cycle, from planting seed to tuber storage. The involvement of multinational companies in biopesticide sales and development will provide credibility and enable growers to consider learning how to use them cost-effectively. There is likely to be difficulties in gaining adoption, so industry will have to gain grower trust by demonstrating not only efficacy, but also cost advantages or at least equivalency.

Potatoes should be considered a perennial crop since the tubers provide the seed source for the next year's crop. Acknowledgement of this reality involves an understanding of the pathogens which recur in the cycle from growing in the field, storage, and then planting in the spring. Biofungicides may be able to help in providing longer-term protection, and so reducing overall losses.

NGOs had been focused on getting rid of the "old chemistry," but there are signs that the recent lull in activity may be over as they start attacking some of the new softer, safer chemicals, such as Bayer's Movento. However, this should not diminish interest in using biopesticides in a program with conventional chemistry.

In recent years, there have been concerns about pesticide residues, which have been detected on potatoes. As a result, the Environmental Working Group categorized potatoes as one of their "Dirty Dozen." The greater awareness of pesticide residues is affecting potato production as well as other produce.

If processors and retail supermarket chains follow the much stricter residue limits being required in European countries, there is likely to be greater interest in using products that are considered natural. This could be exclusively or more likely in conjunction with conventional chemicals, so as to reduce total chemical use and residues to acceptable levels.

Acreage of potatoes

Potatoes are mainly grown in northern states, from Maine to Oregon. The Northwest states of Washington, Idaho, and Oregon produce potatoes on 48.7% of the total U.S. acres, with 45.6% of the total value. Other major states are North Dakota, Wisconsin, Maine, and Colorado.

Table 36: Planted Acreage and Value of Potatoes in Selected States in the United States, 2015

State	Planted acres	\$ Million
Idaho	323,000	941
Washington	165,000	738
Wisconsin	63,000	254
California	35,400	229
North Dakota	82,000	208
Colorado	57,700	177
Michigan	46,000	179
Minnesota	41,000	155
Maine	51,000	149
All other	202,500	913
Total	1,066,600	3,943

SOURCE: USDA NASS, July 2016.

Factors affecting potato production

The high cost of potato production and specialized equipment has combined with difficult market conditions to result in increased consolidation of potato producers. This has been mirrored by consolidations in the value chain, from larger processors to more regional and national supermarket chains.

In fact, the 2012 Ag Census does indicate some growth in the number of larger farms but the total number of potato farms has increased significantly. There were 15,014 potato farms in the 2007 Census and 21,079 in 2012 of which 87% were between 0.1 and 4.9 acres. While these very small farms producing potatoes for local markets did increase in total acreage, their percentage of the total is still small. Yet they may represent an opportunity for biopesticides, since local producers are likely to be either organic or sustainable growers, and so represent a valuable market for smaller packs.

Obviously, the much fewer large growers represent the major market, but they are being held to narrow margins and will require strong performance data to justify greater use of biopesticides.

Finally, the potato market has been affected by concern about chemical residues and sustainability. There is pressure for sustainability. In fact, the National Potato Council (NPC) has been involved in many different efforts to develop a workable definition of sustainability. Potatoes are the first specialty crop to be evaluated using the Field to Market tools developed for the Stewardship Index for Specialty Crops (SISC) for Sustainable Agriculture (NISA). NPC has been encouraging these groups to develop a common set of metrics that are grower-friendly, use largely available data, and measure results over time, rather than establishing bright-line standards.

Major diseases of potatoes

The major diseases that can cause losses in potatoes in storage include:

- Pink rot (*Phytophthora erythroseptica*)
- Pythium leak (*Pythium ultimum* and other spp.)
- Late blight (*Phytophthora infestans*), dry rot (*Fusarium sambucinum*)
- Soft rot (*Erwinia carotovora* subspecies *Atroseptica*)
- Silver scurf (*Helminthosporium*)
- Black dot (*Colletotrichum coccodes*)
- Early blight (*Alternaria solani*)
- White mold (*Sclerotinia sclerotiorum*)

Fungal pathogens can reduce the number and vigor of sprouts growing from the seed piece so that seed treatment is strongly recommended to provide early control and protection.

Diseases can cause losses at all stages, from seed pieces at planting and during early growth, to foliar diseases, and then in storage.

Verticillium Wilt (*Verticillium spp.*) can affect growth and cause early senescence, reducing crop yields, and is serious in the Pacific Northwest.

The major foliar diseases are well-known. Late blight is the most serious, particularly in more humid areas. Early blight can be troublesome, and white mold is a particular problem in the Pacific Northwest. Pink Rot (*Phytophthora erythroseptica*) is an important disease of potatoes around the world, and can cause heavy losses in storage, and predispose the tubers to bacterial rots. Dry rot (*Fusarium sambucinum*) can cause up to 25% crop loss and more than 60% in storage. Soft rot (*Erwinia carotovora*) is a bacterium and one of the most serious storage diseases. Silver scurf (*Helminthosporium solani*) is present in all major production areas in the United States and causes brown blemishes that develop on the tuber surface which can lower the market value of the crop. Common scab (*Streptomyces spp.*) does not usually impact yield, but can reduce tuber marketability.

Major insects

Insects include:

- Aphids
- Colorado potato beetle
- Flea beetles
- Leafhoppers
- Psyllids (*Bacteriocerca cockerelli*)

Nematodes can also cause serious yield reductions, particularly Columbia lance nematode (*Hoplolaimus columbus*) in the Pacific Northwest and other states and its association with *Verticillium wilt*.

Golden nematode (*Globodera rostochiensis*) is being contained in a small area of New York State by severe quarantine measures.

Biopesticides used on potatoes

There are a number of biopesticides registered and labeled for use in potatoes in the United States. Since all stages of potato are highly susceptible to fungal and bacterial pathogens there are products recommended for all stages of its crop cycle.

Potato seed pieces are very susceptible to a range of soil pathogens and nematodes, so treatment ensures that the developing shoots and roots can develop normally.

Respondents were asked about the use of biologicals and were not aware of any major commercial use currently. Comments included, “nobody can get them to work,” and “they have been evaluated and nothing stands out.”

Selected labeled biopesticides

There are many biopesticides with label recommendations for use in potatoes.

Isagro USA received registration for the pre-plant biofumigant, Dominus brand allyl isocyanate, in September 2013 and commercialized the product in 2014, except in California. The product is labeled for the control of insects, diseases, weeds, and nematodes.

Use of biopesticides in vegetables

The list of biopesticides that are labeled for use in vegetables is extensive and looks similar to the lists shown earlier for active substances, targets, and companies. At a recent IR-4 meeting in September 2014, Dr. M.T. McGrath, Cornell University listed biopesticide “products in greatest use in vegetables” and “other products used.”

Based on Kline’s research, the list of biopesticides registered and available is quite long.

Table 37: Biopesticide Products in Greatest Use and Other Products Used in the United States as Estimated by Cornell University, 2014

BIOPESTICIDES IN GREATEST USE IN VEGETABLES	
Phosphorous acid fungicides e.g. ProPhyt, Phostrol	Actinovate
Oxidate	SoilGard
Contans	Double Nickel
Regalia	Serenade Optimum
Trilogy and other botanical oils	Serenade Soil
OTHER BIOPESTICIDE PRODUCTS USED IN VEGETABLES	
Bact-Stop EF400	Mycostop
Bio-Tam, Tenet	Oso
Milstop and Kaligreen	Rootshield
Mildew Cure	Sonata
	Zonix

Table 38: Biopesticide Products Used on Vegetables in the United States with Sales Greater Than \$200,000, 2016

Active	Product brands	Supplier-a
Azadirachtin	Agroneem, Debug, Amazin, Ecosin, Azatrin, Neemazad, Azakaranj, Azera, Azatrol, others	Agro Logistics, Certis, MGK, PBI Gordon, Custom Liquid, BioWorks, Gowan, others
<i>Bacillus pumilus</i>	Sonata, Ballad Plus	Bayer
<i>Bacillus subtilis</i>	Rhapsody, Serenade, Serenade Ma1, Serenade Soil, Cease Quick Roots, Rhizopro	Bayer, BioWorks, Monsanto, TJ Technologies
<i>Bacillus thuringiensis</i>	Agree, Design, Florbac, Jackpot, Ketch Crymax, Condor, Thuricide, Javelin, Deliver	Certis, BioBest, Int Technology
<i>Beauveria bassiana</i>	Mycotrol, Botanigard, Bio-Power	Arbico, BioWorks, and others
Calcium polysulfide	Lime sulfur	Brandt
Calcium polysulfide	Lime sulfur	Novo Source, TKI
<i>Coninthyrium minitans</i> CON/M/91-08	Contans WG	Prophyta: Encore Technologies, Sipcam
Copper octanate	Cueva	Certis
<i>Gliocladium virens</i> GL-21	SoilGard	Certis
Harpin protein	N-Hibit Gold CST, Messenger, Proact, Employ	Plant Health Care, Eden BioScience
Hydrogen dioxide/peroxyacetic acid	Sanidate	BioSafe Systems
Hydrogen peroxide	Green Clean, TerraClean, Zerotol, Oxidate, Bioside, Rendition	BioSafe Systems, Certis
(Continued)		

Table 38: Biopesticide Products Used on Vegetables in the United States with Sales Greater Than \$200,000, 2016

Active	Product brands	Supplier-a
Iron phosphate	Sluggo	Certis
Iron phosphate/spinosad	Sluggo Plus, BugON-Sluggo	Brandt
Kaolin clay	Surround, Snow Plus	Novo Source, TKI, Wilbur Ellis
<i>Paecilomyces fumosoroseus</i>	PreFeRaI, PFR-97, Priority	Certis, BioBest, T. Stanes
<i>Penicillium bilani</i>	Jumpstart	Monsanto
Phosphoric acid	Fungiphite, Phorcephite, Phostrol, Propht, Rampart, Reveille	Nufarm, Plat Protectants
Polyoxin D	PH-D	Arysta
Polyoxin D Zinc	Tavano	Certis
Potassium bicarbonate	Armcarb, Bi-Carb, Kaligreen, Milstop, Remedy, Kaligreen	BioWorks, Brandt, Bonide, Helena
Potassium salts	Des-1	Certis
Potassium silicate	Sil-Matri1	Certis
Pyrethrins	Pyganic, Pyrellin, Pyrenone	MGK, Brandt
<i>Reynoutria sachalinensis</i>	Regalia, Regalia Ma11, Milsana	Marrone
Rosemary	Ecotec	Brandt
Streptomyces	Actinovate, Opportune	Monsanto

a- Only major supplier sales are captured in this report; in general, product sales of \$200,000 or greater was set as the minimum sales level.

SALES BY PRODUCT CATEGORY

Contrary to field crops, vegetables are more reliant on minerals than they are on microbes, although both are important biopesticide categories. Minerals total \$30.3 million in sales, or 34.2% of the market, while bacteria total \$29.4 million, or 33.3% of the total. Botanical extracts account for an additional 25.8% of the total vegetable biopesticide market. Kline's assessment is that the total U.S. vegetable market for all pesticides is about \$820 million, so biopesticides account for 11% of pesticide use.

Table 39: Biopesticide Sales on Vegetables in the United States by Product Category, 2016

Category	Representative brands	\$ Thousand	% Of total
Minerals	MH30, Sprout Stop, Fungiphite, Phorcepphite, Phostrol, Oxidate, Green Clean, Zeroto, Bi-Carb, Kaligreen, PH-D, N-Hibit Gold CST, Messenger, Proact, Surround, Snow Plus, Lime Sulfur, Azera, Amicarb, Agrneem	30,250	34.2
Microbes	Quickroots, Rhapsody, Serenade, Agree, Jackpot, Sonata, Crymax, condor, Cease, Javelin, Thuricide, Regalia Maxx, MilsanaJumpstart, Actinova, Opportune, SoilGard, Mycotrol, Botanigard, Contans WG	29,400	33.3
Botanical	Pyganic, Pyrellin, Pyrinone, Ecotec, AzaD, Neem Oil, Trilogy, Regalia	22,820	25.8
Fermentation Product	Gibpro, Harpin, Myconate, Fireline, Spear	4,350	4.9
Pheromone	No Mate	700	0.8
All other		900	1.0
Total		88,420	100.0

SALES BY ACTIVE MATERIAL

The total market for biopesticides on vegetables and potatoes in the United States is estimated to be \$88.4 million at the grower's level. Minerals are the largest class of products, including phosphoric acid, copper, and sulfur at \$30.3 million. Microbes are the second-leading class with sales of \$29.4 million, while botanical extracts come third at \$22.8 million.

SALES BY SUPPLIER

Sales by supplier of biopesticides to vegetable growers is more fragmented than some other segments, with 11 firms sharing just over 80% of the market. Certis is the leading supplier to the vegetable biopesticide segment with sales of \$21.6 million, or 24.4% of the total segment sales, followed by Valent, Marrone, and Nufarm. Valent has benefited by the addition of MGK's pyrethrin product line with its B.T. products. Certis has by far the broadest product line for the vegetable market with several staple biopesticides, including B.T.'s, Neem products, Copper and microbes.

Table 40 Biopesticide Sales on Vegetables in the United States by Company, 2016

Supplier	Major brands	\$ Thousand	% Of total
Certis	Azatin, Neemazad, Neemix, Agree, Jackpot, Florbac, Condor, Thuricide, Javelin, SoilGard, Trilogy	21,600	24.4
Valent	Pyganic, Pyrellin, Pyrenone, Azera, Vectomax, Ditera,	15,200	17.2
Bayer	Rhapsody, Serenade (3), Cease, Sonata, Ballad Plus	8,500	9.6
Marrone	Regalia, Regalia Maxx, Milsana	7,000	7.9
Nufarm	Fungiphite, Phorcephite, Phostrol, Rampart, Reveille	4,250	4.8
Brandt	Bicarb, Kaligreen, Ecotec, Sluggo Plus, BugOn-Sluggo, Lime Sulfur	3,670	4.2
Novo Source	Surround, Snow Plus, Lime Sulfur	3,500	4.0
Arysta	PH-D	3,700	4.2
BioWorks	Amicarb, Bi-Carb, Kaligreen, Milstop, Remedy	2,800	3.2
BioSafe Systems	Oxidate, Green Clean, Terra Clean, Zertol, Sanidate, Axxe	2,000	2.3
Custom Liquid	Azakaranj	1,000	1.1
Plant Health Care	N-Hibit Gold CST, Messenger, Proact, Emphy	300	0.3
Plant Protectants, Inc	Fungiphite, Phorcephite, Phostrol, Rampart, Reveille	100	0.1
All other-a	-	14,800	16.7
Total		88,420	100.0

a-Includes phosphoric acid, maleic anhydride, and Bt sulfur that could not be split out by company, plus Amvac, Arbico, PBI Gordon, Sipcam, and Propytha.

SELECTED CROP PRODUCTION AND EXTENSION RESPONDENT COMMENTS

Independent results from efficacy results available through the IR-4 program indicate that only a few of the products were considered effective. Results on powdery mildew were favorable, particularly organocide 5% and sesame oil, and many products were found to be effective for the control of downy mildew in cucurbit crops.

Respondents reported that growers were generally using broad spectrum fungicides, such as chlorothalonil and mancozeb, as they usually provide reliable levels of control at a reasonable cost. There are very few products that provide control of bacterial diseases and soil pathogens. Sipcam's Contans WG *Coniothyrium minitans* strain CON/M/91-08 is an example of a biological fungicide to reduce/control *Sclerotinia sclerotiorum* and *S. minor* in soil.

A vegetable extension respondent commented that the growth of organic vegetables has lead to an increase in biopesticide use. The available products are effective for this application and control most of the major pests.

Another respondent considered biopesticides to be “more specific and as expensive or more expensive as conventional alternatives so there must be a good reason to use them. Growers often do not get what they pay for, so that biopesticides have not been so widely used. Organic growers have no options. Chlorothalonil and mancozeb are cheap and effective, so farmers will make their choice based on their reliability, efficacy, and cost. Products must work reliably and consistently. Common experience has been that they do not work under high disease pressure and may not be able to perform even under the best conditions.”

FACTORS AFFECTING THE MARKET FOR BIOPESTICIDES IN VEGETABLE CROPS

Cost of production, particularly of crops that require irrigation and staking, is high, so growers must be able to rely on products that can provide assured control. This is not to discount the willingness of growers to change their practices, such as timing in relation to the time of day and frequency, if they can be assured of satisfactory results.

Pesticide residues

Pesticide residues are of concern, particularly those vegetables with extensive leaf area. USDA 2011 data indicated that 66.7% of head lettuce was without residues, whereas only 14.3% of leaf lettuce samples were residue free. In spinach, only 23.1% of samples were without residue, and one was over the tolerance. The only vegetable that had a sample over the tolerance was a squash, and 56.2% were without residues. Supermarket chains and food processors are increasingly concerned about pesticide residues.

The Environmental Working Group (EWG) publishes the Dirty Dozen of crops, which residue data has shown to be of greatest risks to consumers. Leafy greens and hot peppers were found to have residues of more toxic pesticides, such as acephate, chlorpyrifos, oxamyl, famoxadone, and esfenvalerate. It was noted that since 2008, several of the products may no longer be labelled for the most susceptible crops. The report notes that various vegetables, such as celery, kale, collard greens, tomatoes, and fruits, such as nectarines, peaches, strawberries, and cherries have not been tested since 2008 and are overdue for testing.

The pressure to produce vegetables with no residues or no detectable residues will continue, so that growers will look for affordable alternatives that provide maximum flexibility to control diseases and insects that could reduce quality. Most biopesticides have zero harvest intervals and so are attractive if they can achieve control equal to chemicals. Powdery mildew is a good example of a disease that appears to be efficiently controlled by several biofungicides.

Protection through harvesting

Many of the vegetables need to be protected through harvesting time so that the required harvest intervals restrict growers in their choice. Mancozeb, for example, has a five-day interval before harvesting, so that a product such as Regalia with PHI (Pre-Harvest Interval) of 0 days and REI (Re-Entry Interval) of four hours should be of interest to control three of the major diseases of tomatoes. Cease, *Bacillus subtilis*, is effective on mildew and can be applied very close to harvest.

Resistance

Resistance has been developing in several fungicide and insecticide chemical groups. Although there is usually choice of a conventional product with a different mode of action that provides equivalent control, respondents made it clear that biopesticides could play a role in delaying resistance. Resistant strains of *Phytophthora* spp. to metalaxyl are not uncommon, and several biopesticides work well. The effective life of a standard chemical can also be extended by combining or alternating it with appropriate biopesticides.

Diseases difficult to control

Soil diseases such *Verticillium*, *Fusarium*, and *Phytophthora* have been found to be difficult to control even with fumigants. Root Shield, Actinovate, Cease, and Companion were reported as providing “good success.” Application of some of the soil applied biopesticides to expensive transplants was found to give longer control than traditional fungicides. While crop rotation is the recommended means of keeping soil diseases in check, land and market pressures may result in more intensive cropping with higher soil disease levels. Biopesticides can play a particularly useful role in protecting the developing plants.

Impact of changing cultural practices

In California, the two factors of tough-to-control pathogens and resistance development have been exacerbated by installing drip lines for multiple-year production so that tomatoes tend to be grown more frequently. About 95% of processed tomatoes are now transplants, which also tend to enhance nematode infestations. Changing field practices are often resulting in even more serious soil infestations.

Recent legislation

Recent legislation has made it increasingly difficult and expensive to use fumigants. Growers are being encouraged to adopt programs that enable beneficial organisms such as mycorrhiza to develop and utilize biopesticides to target plant pathogens and enhance the crop plant’s own defense systems.

Value of performance data and sound labels

Companies supplying biopesticides must be able to supply sufficient data and precise recommendations to enable growers to gain successful use. The breadth of diseases, for example, controlled on product labels have not always been shown to be realistic.

Cost

Ingredient costs have occasionally reached such levels that economic use has been prohibitive, except in exceptional circumstances. Regular use will only be achieved when products provide value for the cost.

Reputation

Smaller companies, particularly newly established companies, must work harder to gain attention. Larger companies that have an established reputation will have a better chance of getting attention and trial use.

Particular nature of vegetables

While these last points apply to other market segments as well they are of importance in the vegetable sector where growers tend to be quite large and their crops are perishable and valuable.

OPPORTUNITIES FOR BIOPESTICIDES IN VEGETABLES

The role of consumer concerns will further encourage growers, shippers, and supermarket chains to promote chemical-free and sustainable methods used to grow fresh produce and also processed vegetables. Biopesticides will be able to play a valuable role, if not during the whole growth cycle, at least at key points, such as before harvesting.

For vegetable producers involved in or considering export markets, biopesticides can be valuable in reducing if not avoiding residues, so that there will be no problem in meeting importing country requirements.

Several food processors and supermarket chains have policies that indicate their definite move to products that are produced more sustainably. Food and produce companies will use more labels, indicating that their products are “natural” or “locally produced,” and “sustainable,” with efforts to ensure their producers are practicing IPM and minimizing the use of chemicals.

Conventional products do not provide effective control of all insects and pathogens and nematodes, such as the bacteria black rot of crucifers (*Xanthomonas campestris* pv. *campestris*), tomato bacterial speck and spot (*Pseudomonas syringae* pv. *tomato*), and soil-borne pathogens such as *Phytophthora capsici* and *Verticillium* spp.

In organic production, there are many common diseases such as Botryis, leaf mold, and powdery mildew in high tunnel tomatoes, and many other common diseases in standard production. Viral diseases are also not addressed with the current armory of pesticide products, and producers would like to have a product that would control aflatoxin.

A recent listing produced at the IR-4 Biopesticides Workshop in September 2014 the need for control measures in organic production that can control certain diseases and insects. In the order of priority, these were:

- Bacterial diseases of fruiting vegetables – both field and greenhouse
- Downy mildew in basil—field and greenhouse
- Whitefly, aphids, and psyllids in greenhouse tomatoes
- Mites, thrips, aphids, and whiteflies in vegetables
- Thrips in all crops, *Phytophthora capsici* in field vegetables

ORGANIC PRODUCTION

Organic production represents a relatively small percentage of the total farmland in the United States. However, there has been steady growth in the acreage and value of certified organic production. This section will attempt to review the organic market as being a ready but limited market for biopesticides.

Producers can only claim certified organic when their farm has been certified by the USDA. Any farm with sales of over \$5,000/year must be certified to market certified organic.

The available statistics only cover those farms with USDA certified organic acres of crops and livestock. There is likely to be more acres that are organic, but not certified by USDA.

The consumption of organic foods has been increasing, but still represents only about 4% of the food consumed, although continued growth is expected.

While the market is small, it does represent an obvious potential for biopesticides since only products that are certified for use on organic crops can be applied. Increasingly, organic production is on large-scale farms that are able to benefit from the organic premium, but yet be able to produce economically.

Market for organic crops

The booming U.S. organic industry posted new records in 2015, with total organic product sales hitting a new benchmark of \$43.3 billion, up a robust 11% from the previous year's record level, and far outstripping the overall food market's growth rate of 3%, according to the Organic Trade Association's 2016 Organic Industry Survey.

The industry saw its largest annual dollar gain ever in 2015, adding \$4.2 billion in sales, up from the \$3.9 billion in new sales recorded in 2014. Of the \$43.3 billion in total organic sales, \$39.7 billion were organic food sales, up 11% from the previous year, and non-food organic products accounted for \$3.6 billion, up 13%. Nearly 5% of all the food sold in the United States in 2015 was organic.

Over two-thirds of U.S. consumers now buy organic foods occasionally, and retailers have not always been able to keep up with the demand.

Organic fruits and vegetables retained its longstanding spot as the largest of all the major organic categories with sales of \$14.4 billion, up by 10.5%. Produce has always been and continues to be a gateway to organic. It is easy for shoppers to make the connection between agricultural practices used in the field and the fresh fruit or vegetables they bite into. Almost 13% of the produce sold in this country is now organic.

The demand for fresh organic was most evident in the continued growth of "fresh juices and drinks," which saw explosive growth of 33.5% in 2015, making it the fastest-growing of all the organic subcategories. The fastest-growing of the eight major organic categories was condiments, which crossed the \$1-billion mark in sales for the first time in 2015, on 18.5% growth.

Organic imports

Organic food has become much more widely available, and the market has become much more mainstream. Growth has even occurred during the last few years of recession. Imports are mainly tropical fruits which cannot be grown in the United States, but also fresh contra cycle products, which cannot be grown in the United States during that season. Consumers have long been used to being able to buy bananas throughout the year, and they can now also purchase grapes from Chile during winter.

Organic acreage

Certified organic vegetable farms have grown dramatically over the past decade, from about 48,000 acres in 1997 to over 160,000 acres in 2014. Over 15% of all acres used to grow carrots are certified organic. Sales of organic grown crops have also grown dramatically. The 2014 Organic Survey shows that 14,093 certified and exempt organic farms in the United States sold a total of \$5.5 billion in organic products in 2014, up 72% since 2008. California, Washington, Pennsylvania, and Oregon are the largest organically producing states. Over \$250 million in organic lettuce is sold in the United States, and 80% of organic produce is sold within 500 miles of where it is produced.

Producers

There are two broad categories of organic producers. The first group consists of smaller growers who are concerned about health and the environment. They believe in producing crops as naturally as possible, and are frequently involved with farm-to-table sales focusing on the fresh restaurant market. When the USDA first proposed organic standards, genetically modified crops were permitted for certification. This was flatly turned down and exemplifies their commitment to “natural products” although their use of some of the OMRI products, such as copper and sulfur (biopesticide), is significant.

The second group consists of farmers who produce organic crops on a large scale for economic business reasons due to the premium that can be obtained.

An USDA ARMS 2007 survey found that 45% of the farmers chose organic to increase farm income, 23% for the health of their family and community, and 10% wanted to adopt more environmental friendly practices.

Marketing

Initially, production was largely on smaller farms, with sales through local outlets and direct sales. More recently, the volume production of consistent quality products required by the local and national supermarket stores has only been satisfied by large sophisticated growers.

Marketing of organic produce and food started largely on the local level through farmers markets, CSAs, and other direct sales. In recent years, 83% of organic sales are now through wholesalers, processors and distributors, 10.6% to retail operations including supermarkets and natural food stores and only 6.8% direct to consumers through farmers markets, farm stands, and CSAs (Organic Trade Association). Cornell University estimated that only 1.6% of sales are being achieved through direct channels, even though there were 8,144 farmers markets in 2013 versus only 1,755 in 1994.

Walmart, the largest food retailer, announced in April 2014 that the company was expanding sales of organic food to 2,000 of their 4,000 supermarkets. The company also announced that it would be offering its Wild Oats organic products at prices that will undercut brand-name organic competitors by at least 25%.

Insect, disease, and weed control

Certified organic producers can only use those products listed in the OMRI list, which includes over 3,000 products, which meet USDA Certified Organic standards, and so are described as "OMRI Listed." This list includes biopesticide active ingredients and the FIFRA 25(b) products which are exempt from registration, plus a few chemical pesticides that can be used.

Organic products are rarely able to perform as well as modern pesticides and may require more frequent application. The cost may also be higher. Marrone Bio Innovations (MBI) admits that the company can test out new products which may be more expensive as production may not have been optimized for quality and cost.

Regulatory situation

The U.S. organic market is regulated and governed by the USDA under the National Organic Program (NOP). In 2002, the USDA produced National Organic Standards after extensive input from the farming community. Basically, they commit the farmer to dedicate that part of their farm to organic production since the land can only be certified after three years of organic production.

Any substance used on the land must be approved by the certifying agent. Certification requires that producers and handlers must employ stringent pest-management practices and all necessary measures should be taken to prevent the co-mingling of organic with non-organic products and prohibited substances.

In crops, synthetic substances are prohibited unless specifically allowed, such as boric acid and newspaper. Natural substances are allowed unless specifically prohibited, such as arsenic and strychnine. In livestock, some specific synthetic substances are allowed such as vaccines, iodine, and electrolytes, and the natural substance strychnine is an example of a natural substance that is prohibited.

There are four different types of organic labels: 100% organic, Organic, Made with organic (specified ingredients or food groups, and 70% organic.

Any grower producing over \$5,000 worth of produce for sale must be certified to be able to claim Certified Organic. The annual certification costs are around \$800.

Initially, production was largely on smaller farms with sales through local outlets: farmers' markets and other direct sales.

Factors affecting organic production

The two major factors affecting organic growth can be the overall economic climate and prevailing concerns about food safety and personal health.

Increasing per capita income across a wider range of the U.S. population is considered one of the most likely drivers of increased organic sales. Income growth has been confined to a relatively small percentage of the population, so that economic growth forecasts will be important indicators in assessing prospects.

Press and media coverage tends to accentuate problems with conventional farming and accentuates organic and “natural” production. It is unlikely that this will change, so that the more affluent consumers will feel that they are serving their family better by purchasing organic products to ensure greater safety. The even more dubious claim of higher levels of nutrition are not supported by science, but are nevertheless, often believed. For example, “The Centers for Disease Control and Prevention, 2013 estimates” shows that about 1.1 billion pounds of pesticides active ingredients are being used annually in the country and over 20,000 pesticides products are being marketed annually, which is adversely impacting the health of consumers. Therefore, the organic foods which are produced using environmental and animal friendly organic farming methods are gaining awareness in the country. Organic Trade Association 2012 estimates show that about 81% of families are purchasing organic food at least sometimes.”

Organic livestock production, whether dairy or for meat, has been curtailed by the shortage of organic feed caused by the recent high grain prices, demand for corn for ethanol and other factors. Production has been held back as it has not always been possible to recover the higher feeding costs with high enough market prices for dairy and livestock products.

It is likely that the much lower feed prices may encourage more certified and non-certified organic production of livestock products. The current higher prices for meat, both beef and chicken, may also help in encouraging more organic livestock production, which means organic feed, forage, and hay.

All the factors certainly point to continued growth of organic production.

Opportunities for biopesticides in organic production

Other segments of this report have indicated that there are many opportunities for biopesticides in conventional production. Since certified organic producers can only use OMRI certified products, any biopesticides with enhanced performance will be welcomed by organic producers. Quality Assurance International considers that there will be stricter regulation of organic production and that organic will be linked with food safety and “other food integrity programs.” International standards will also be established. Growers will have to use products that meet the new standards and will not wish to risk using conventional products.

Some organizations are forecasting that fruit and vegetables will continue to dominate the organic food category so that there will continue to be good opportunities for effective products that can be used.

A listing of priority targets was voted at the September 2014 IR-4 Biopesticide Workshop:

1. Fireblight in organic apples
2. Weed control in all organic crops
3. Mummy berry (*Monilinia vaccinii-corymbosa*), Anthracnose, Alternaria in blueberries
4. Late blight in tomatoes
5. Downy mildew in pumpkin and squash

Obviously, most if not all of the opportunities listed under the other crop/market segments also apply to this specific organic segment.

There is undoubtedly strong interest in biopesticides that perform well. There is growth in organic production; even though the market is small compared to the conventional market, sales can provide a valuable base.

SPECIALTY CROPS

In this report, specialty crops include the nursery and greenhouse market segments. Total segment sales are \$39,300 million at the end-user level in 2016.

HORTICULTURAL NURSERIES AND GREENHOUSES

The estimated retail value of the horticulture industry, as defined by the American Horticulture Council, is \$15 billion. This includes the nursery and greenhouse producers of plants for sales as flowers and pot plants, as well as any plants/trees for planting by commercial growers or homeowners. It does not cover those growers producing any food items.

The value of total floriculture farm gate sales according to the most recent 2012 Ag Census was \$5.9 billion, a 9.2% reduction compared to the 2007 census total of \$6.5 billion. The downturn in the economy and the lack of new housing development are two reasons for this decline. There is hope that the long-term future is sound as the economy gradually picks up steam.

The relatively small market and high value of the crops has resulted in fewer active ingredients being commercialized. Biopesticides are commonly used. The environment in protected structures has favored the development of microbial organisms, and hence the need to provide a protective barrier against pathogens and certain pests.

Acreage and value of ornamental horticulture

There were 26,884 farms in 2012 growing a wide range of floriculture crops in the open on 52,617 acres and under protective structures covering 873.3 million sq. ft.

It is worth pointing out that unlike most of the other agricultural and horticultural markets, floriculture is very widely distributed, so that 58% of the value of the market is dispersed among other states throughout the country, outside the top seven states.

Table 41: Number of Farms, Area under Protective Cover, Acres in the Open and Value for Floricultural and Bedding Plant Production in Major U.S. States, 2012

State	Number of farms	Sq. ft. under protective cover million	Acres in the open	Farm gate value, \$ million
California	2,140	115	12,535	1,093
Florida	2,013	312	8,525	771
Michigan	1,287	59	2,325	470
Texas	845	51	2,385	373
North Carolina	1,458	24	1,502	287
Ohio	964	25	735	228
Pennsylvania	1,668	20	1,075	199
Other states	16,588	267	23,535	2,464
Total	26,963	873	52,617	5,885

SOURCE: U.S. Agricultural Census 2012 (latest data).

Current market

The relatively small acreage grown both in the open and under cover does not amount to a huge area, but the value is high and estimated to be \$5.9 billion, or \$11,189 per acre (USDA Agriculture Census 2012). Product quality is important so that appearance is very important, requiring close attention to plant protection.

In the United States, it is estimated that 15% of greenhouse growers use biologicals in their IPM programs. Barriers include their slower action, greater preventive than curative activity, and occasional inconsistent results under some conditions.

In Canada, a recent MNP survey of floriculture growers found that 90% used biocontrol and 79% biopesticides. Biocontrol could provide levels of control equal to or better than pesticides for some major pests. Over 80% of respondents to the survey agreed or strongly agreed that a good balance is more effective than the use of pesticides alone.

The market for biopesticides is relatively limited, but the example of Canada provides an example of the potential for biocontrol and biopesticides in greenhouses and ornamental horticulture. There clearly requires a higher level of management to be successful, and this will require greater effort by supplying companies to work with major producers to develop programs that are consistently effective.

High tunnels are becoming more widely used to ensure a longer growing season and even growing some more hardy crops during the winter. Most of the high tunnels are used for vegetables and fruit production, but ornamentals are also raised. Their initial cost is significantly lower than permanent glass greenhouses, and they can be moved. However, the enclosed space can favor disease and insect build-up, and more intensive cropping allows nematode populations to increase. Insects such as aphids, thrips, mites, and worms are prevalent.

Factors affecting the market

This is a high-value market, and crop quality and operator safety are critical. Many different cultural methods are practiced in the open and under cover. In high-value crops that are usually protected by glass or high tunnels, conditions favor both insects and pathogens due to the favorable temperature and humidity. As a result, crop protection is critical, but the relatively small market has meant that few actives are registered and resistance has become a problem.

Range of insects, fungal and bacterial pathogens

A wide range of insect and plant pathogens affect ornamental plants, particularly under glass. Insect populations can build up quickly in a protective culture. Intensive growing conditions favor soil pathogens, such as *Rhizoctonia salami*, *Pythium*, and *Fusarium* spp., as well as *Thielaviopsis*, *Cylindrocladium*, and *Verticillium* species, and other root decay fungi. Control of these diseases has been challenging for conventional fungicides due to the need to drench the soil to get adequate penetration and coverage. There are many bacterial diseases affecting ornamentals such as *Xanthomonas*, *Pseudomonas*, and *Erwinia* species, and the soil inhabiting *Ralstonia solanacearum*. In most bacterial diseases, photosynthesis and respiration are severely altered to the detriment of the plant. Current chemicals such as copper and streptomycin may only achieve 50% control in ornamentals and bacteria appear to be able to develop resistance. Consequently, there is need for products that achieve higher levels of control both on the foliage and on the roots in the soil.

Grower curative mind set

Growers have been used to the curative action of many conventional pesticides and must adapt to the preventative control achieved by biopesticides. They also do not perform well under high population pressure and are more sensitive to environmental conditions such as high temperatures. Such conditions are particularly likely to occur in protected cropping. These limitations have undoubtedly discouraged growers who were not able to gain good results in their first use of biopesticides.

IPM and biocontrol

IPM is widely practiced and the introduction of biocontrol agents (BCAs) has been found to be valuable for the control of insect pests under the growing conditions of protected crops. BCAs are available for all the major greenhouse pests including aphids, caterpillars, fungus gnats, mealy bugs, scales, spider mites, thrips, and whiteflies. Lepidoptera are more likely to be a problem in open greenhouses and high tunnels. A wide range of natural predators are available commercially from over 20 different producers, mostly outside the United States, but with local distributors.

Regulatory impact

The regulatory environment affects producers whose plants cross state borders. State governments make every effort to ensure that plants for planting or use in that state are free from all regulated pests. It is stated that the detection, prevention, suppression, control, or eradication of plant pests is necessary for the protection of agriculture, the environment, and the economy of the state. Therefore, it is necessary to abate, suppress, eradicate, and prevent by such means as shall be prescribed and provided by law or by rule, order, or regulation of the department, all contagious, infectious and plant pests destructive to the state's agricultural, forestry or horticultural interests or to the state's general environmental quality. An organism under the Regulated Pest designation must be at zero level to cross the state border.

Under recommended guidelines for a Model Plant Pest Law, any premises, plants, plant products, or other articles which are found to be infected or infested with any plant pest may be held and declared a public nuisance.

Regulated Article refers to any article of any character, carrying or capable of carrying a plant pest for which quarantine has been established.

Regulated non-quarantine pest

A non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the United States or the state by an authorized plant protection organization.

Plant pest

Plant pest is considered any living stage of a protozoan, a non-human animal, a parasitic plant, a bacterium, a fungus, a virus or viroid, an infectious agent or other pathogen, or any article like or allied with any of these articles that can directly or indirectly injure, cause damage to or cause disease in any plant or plant product.

Every effort is being taken to prevent the spread of organisms likely to spread and cause losses. This places significant pressure on nurseries to ensure that their monitoring and insect and disease control practices are rigorous.

Clearly, producers of nursery stock will be under increasing regulatory pressure to ensure the highest level of plant protection.

Neonicotinoids

A real concern in the horticulture industry, as in other segments, is the pressure being placed by environmentalists for the government to restrict use of the neonicotinoids. This family of insecticides is widely used and provides control of a wide range of insects. Biopesticides offer alternatives, although use patterns must adapt to the more preventive mode of action.

Selected biopesticide products

This section lists some of the products currently available and labeled for insect and pathogen control. Many of the biofungicides control a wide range of diseases.

Several of the biofungicides, both fungi and bacteria, make plant health and growth claims. Fungal species, such as *Trichoderma harzianum* T-22 (sold under Triatum-G), can out-compete the pathogenic fungi, growing round the pathogens, as well as strengthening the plant. It increases the resistance of plants to stress caused by disease, sub-optimal feeding and watering regimes, or climatic conditions, and increases nutrient uptake.

Streptomyces lydicus WYEC 108 (Actinovate AG) colonizes the root system and protects it from damaging fungi. Both products are largely preventive and therefore need to be applied in the very early stages of infection to provide control.

Biopesticides sales by classification

Bacteria, biochemical, and fungi are the leading classifications of biopesticides used in the nursery/greenhouse industry. Biotanicals is the leading classification with sales of \$13.9 million or 35.4%, followed by microbes with sales of \$11.45 million or 29.1%.

Table 42: Selected Biopesticide Active Substances, Trade Name(s), Target Insects and Supplying Companies Labeled for Use in Floriculture and Ornamental Horticulture in the United States, 2016

Organism	Trade name(s)	Target insects	Company
<i>Bacillus thuringiensis aizawai</i>	Xentari, Florobac, Agree, Design, Ketch	Caterpillars	BioBest, Certis, International Technology (IT), Valent
<i>B.t. israelensis</i>	Many	Fungus gnats	Many
<i>B.t. kurstaki</i>	Thuricide, Dipel + many others	Caterpillars	Many
<i>Metarhizium anisopliae</i>	Met 52 ec	Thrips, whiteflies and mites	Novozymes
Nucleopolyhedrosis virus (NPV)	Gem-Star, NPV, Spod-X	Caterpillars	Certis, Rincon-Vitova
<i>Paecilomyces fumosoroseus</i>	PreFeRal, PFR-97	Aphids	Certis
<i>Paecilomyces fumosoroseus</i> FE9901	NoFly	Many insects	Natural Industries
<i>Saccharopolyspora spinosa</i>	Entrust	Caterpillars, beetle larvae, thrips, leafminers	ARBICO
<i>Verticillium lecanii</i>	Vertalec, Mycotal	Aphids in greenhouses	Koppert

Table 43: Selected Active Substances, Trade Name(s), and Supplying Company for Biofungicides in Floriculture and Ornamental Crops in the United States, 2016

Organism	Trade name(s)	Supplying company or companies
<i>Ampelomyces quisqualis</i>	AQ10	
<i>Coniothyrium minitans</i> CON/M/91-08	Contans WG	Prophtya/Sipcam Agro
<i>Gliocladium virens</i> GL-21	SoilGard	Certis USA
<i>Trichoderma hamatum</i> 382	NA	Sylvan Bioproducts
<i>Trichoderma harzianum</i>	RootShield, PlantShield	Bioworks
<i>Trichoderma harzianum</i> T22	Mycotal	Koppert
MICROBIAL		
<i>Bacillus subtilis</i> GB03	Companion	Growth Products
<i>Bacillus subtilis</i> MBI 600	Subtlex NG	Becker Underwood (BASF)
<i>Streptomyces griseoviridis</i> Strain K61	MycoStop	AgBio
<i>Streptomyces lydicus</i> WYEC 108	Actinovate AG, Actino-iron	Novozymes
PLANT DERIVED OR CHEMICAL NATURAL SUBSTANCES		
Neem oil	Trilogy	Certis USA
Plant oils	Mildew Cure	Biotech Inc.
Potassium bicarbonate	Milstop	BioWorks
<i>Reynoutria sachalinensis</i>	Regalia	Marrone BI

Table 44: Biopesticide Sales Used by Nurseries and Greenhouses in the United States by Classification, 2016

Biopesticide classification	Representative brand(s)	\$ Thousand	% Of total
Botanical	Azera, Amazin, AzaGard, Azakaranj, Sanidate, N-Hibit Gold, Messenger, Proact, Bioside, Regalia, Regalia Maxx others Trilogy, Green Light, Neem oil	13,900	35.4
Microbiol	Subtlex, HiStick, Vault, Gallex, NogallK, Tentari, Dipel, Lepinox, Crumax, Thuricide, Javelin, Milsana, Actinovate, Met 52, Bio-Magic, PreFeRaI, PGR 97	11,450	29.1
Mineral	Armcarb, Bi-Carb, Kaligreen, Green Clean, Terra Clean, S	8,950	22.8
Beneficial nematode	Nemasys, NemaShield	3,700	9.4
Viruses	Spod-X (Exigua)	700	1.8
Fermentation product	PGR IV	600	1.5
Total		39,300	100.0

Sales by active ingredient

Total sales of biopesticides to the nursery/greenhouse market are \$39.3 million in 2016. The leading active ingredients are *Paecilomyces fumosorosis*, sold under the names of NoFly, Preferal and PFR-97 and Azadirachtin, with sales of \$6.8 million and \$6.5 million, or 17.3% and 16.5%, respectively. Hydrogen peroxide/hydrogen dioxide is the third-leading active ingredient with sales of \$5.6 million or 14.2%.

Table 45: Biopesticides Sales to Nurseries and Greenhouses in the United States by Active Ingredient, 2016

Active	Brand(s)	\$ Thousand	% Of total
<i>Paecilomyces fumosorosis</i>	NoFly, preferal, PFR-97	6,800	17.3
Azadirachtin	Agroneem, Debug, Amazin, Eczin, Ornazin, AzaGard, Motl-X, Azatin, Neemazad, Azakaranj, Aza-Direct, Azatrol, Azera, other	6,500	16.5
Hydrogen peroxide/Hydrogen dioxide	Green Clean, Biocide, Xeroton	5,600	14.2
Gibberellic acid (and Combos)	Progib, PGR V, Gravity, ProVide	2,700	6.9
Steinernema (all species)	Nema shields, Millenium, Nemasys	2,300	5.9
Neem Oil	Trilogy, Green Light	2,000	5.1
Trichoderma (all species)	Trianum, Trichor plus	1,200	3.1
Spodoptera e1igua NPV	Spod-X	700	1.8
<i>Bacillus subtilis</i> MBI 600	Subtilex, HiStick, Vault HP	500	1.3
Iron Phosphate	Sluggo	300	0.8
Potassium bicarbonate	Armicarb, Bi-Carb, Kaligreen, Milstop, Remedy	300	0.8
All other-a		10,400	26.5
Total		39,300	100.0

a- Includes *Bt kurstaki*, copper octanate, polyoxin D Zinc, ammoniated soap, and others.

Sales by supplier

The greenhouse biopesticide market is very diffuse, with many players with small market shares. Biosafe systems is the largest supplier of biopesticides to the greenhouse/nursery trade with sales of \$6.0 million, or just over 15.3% of the market. Valent and Natural Industries share the second-leading place, both with sales of \$5.0 million or 12.7% each. Certis, who was the leading supplier in 2014 has dropped in the rankings due to its agreement with Olympic to market Triact and Soilgard in the nursery/greenhouse market. The general perception is that this is a market that could see some consolidation.

Table 46: Biopesticide Sales to Nurseries and Greenhouses in the United States by Supplier, 2016

Supplier	Representative brand(s)	\$ Thousand	% Of total
BioSafe Systems	Oxidate, Green Clean, Terra Clean, Zertol, Sanidate, Axxe	6,000	15.3
Valent	Dipel, Biobit, Foray, Xentari, Gibberillic acid	5,000	12.7
Natural Industries	NoFly	5,000	12.7
Sepro	Perferal, Copco,	3,250	8.3
Koppert	Triatum, Vertilac	3,000	7.6
Olympic	Triact Soilguard	3,000	7.6
Gowan	Aza-Direct, Sythe	2,700	6.9
Phyton	Xerotol	2,500	6.4
Biobest	B-Green, Preferal, 4.8	1,900	4.8
Certis	Azatin, Neemazad, Neemix, Agree, Jackpot, Florbac, Condor, Thuricide, Javelin,	1,100	2.8
BASF	Subtlex, HiStick, Vault, Nemasys, NemaShield	1,100	2.8
BioWorks	Amicarb, Bi-Carb, Kaligreen, Milstop, Remedy	800	2.0
Lam International	Mycotrol, Botanigard	750	1.9
Arysta	PGR IV	600	1.5
Brandt	Fungiphite, Phorcephite, Phostrol, Rampart, Reveille	100	0.3
All other-a		2,500	6.6
Total		39,300	100.0

a- Includes Agro Logistics, Custom Liquid, PBI Gordon, Amvac, others

Fungal and microbial pathogens

The intensive nature of most floriculture and ornamental production, particularly under protected structures, results in conditions ideal for pathogens to flourish. They require attention from growers to prevent loss of plants and reduction in quality. Genera include alternaria, botrytis, cladosporium, cylindrocladium, didymella, erwinia, fusarium, powdery mildew, pseudomonas, pythium, rhizoctonia, thielaviopsis, uncinula, and verticillium. There is a very wide range of different plant genera involved, so it is not surprising that a wide range of pathogens needs to be controlled, particularly on a production site with multiple crops. Many of the microbial fungicides have very broad labels in terms of both pathogens controlled.

Opportunities for biopesticides

There are biological and market reasons for increased use of biopesticides.

- **Integrated Pest Management:** It has become widely established on ornamental and plant nurseries; biopesticides generally are specific in action and do not affect natural predators and biocontrol agents.

- Control of bacterial diseases: Several bacterial diseases can be controlled by biopesticides, particularly where copper or streptomycin resistance has developed.
- Higher insect and disease pressure: The special environment in protected structures can exacerbate insect and disease infestation and also provide suitable conditions for the successful use of biocontrol. “Soft” products are essential for use in biocontrol so the use of the more selective biopesticides makes them more compatible partners by not affecting the predacious species.
- Improved crop quality and yield: The Canadian report also found that reduction of pesticide use lowered crop stress and so improved crop quality and yield. Canada is considered to be a world leader in biocontrol use in floriculture greenhouses.
- Safer products: Most greenhouse crops are labor intensive, and the use of products that are safer to operators is clearly highly desirable. Biopesticides usually have much shorter re-entry intervals (REIs) so enabling workers to work in treated areas and carry out their activities with no health concerns. Consumers also have to be assured that they are purchasing plants or flowers that do not have any hazardous spray residues. According to the Greenhouse Grower Magazine, there is a general agreement that the buying public wants the industry to use the safest products available, and these products should be viewed in that light.
- Multiple resistance has developed to several of the major fungicides and insecticides based on the current modes of action (MOA). Since biopesticides generally have multiple modes of action, they can provide control of resistant pathogens and insects. However, current biopesticides have more preventive rather than curative action, so use patterns have to be developed that allow them to be used effectively. They can be effectively combined or alternated with conventional products. Advisers usually recommend early application as in the example of Western Flower Thrips (*Frankliniella occidentalis*), which is a serious pest, often with resistance to some conventional insecticides. Early application of a microbial pesticide before infestations level build up, not only provides early control but prevent resistant populations developing or increasing.
- Some growers have reported that they had moved away from relying on conventional pesticides due to pesticide resistance, the scarcity of conventional pesticide products and the high efficacy they had been able to achieve with biocontrols.
- Soil fumigants provide broad spectrum control of pathogens in the soil but are expensive and increasingly require more draconian requirements for application and reporting. Biopesticides avoid this problem, and planting can take place without delay. Products such as RootShield Plus, SoilGard, Actinovate, Contans, and Mycostop have been shown to provide good control of several soil pathogens.

NON-CROP MARKETS

The non-crop segment of the biopesticide market includes a disparate group of markets, including the following:

- Pest control
- Mosquito control
- Turf
- Forestry
- Aquatic

SALES BY MARKET

The non-crop segment accounts for \$68.3 million at end-user level sales in the United States. The pest control market is projected to be the largest segment with sales of \$38.6 million, followed by mosquito control at \$17.0 million, with turf, aquatic and forestry being much smaller.

Table 47: Sales in the Biopesticide Non-crop Segment in the United States by End-use Market, 2016

Market	\$ Million	% Of total
Pest control	38.6	56.5
Mosquito control	17.0	24.9
Turf	9.9	14.5
Aquatic	2.0	2.9
Forestry	0.8	1.2
Total	68.3	100.0

PEST CONTROL

The pest control market is defined as those pesticide products applied by licensed applicators to residential and commercial structures to control insects and small animal pests. This sector has long been active in the use of biopesticides, primarily with various active ingredients, including pyrethrin, a plant extract from chrysanthemum; orthoboric acid, a natural biochemical; and diatomaceous earth, a naturally occurring sedimentary rock that crumbles into a fine powder. Other important substances include d'limonene, silica, and essential oils.

Many home owners and all food handling establishments have an expressed need for safety in the products that they apply. Pyrethrin is considered relatively safe and has found a niche among safety-conscious pest control clients and in food preparation areas. Of course, synthetically produced pyrethroid insecticides have supplanted some of the natural pyrethrin uses in the last 30 years, but the natural product retains a strong niche in pest control. Safety considerations have also resulted in the emergence of a relatively strong position for orthoboric acid and the limited use of 25-B products based on botanical extracts. In addition, pheromones are used to attract and control insects in storage facilities and warehouses.

These biopesticides are positioned within a much larger structural pest control market, which is described below.

Traditional pest control market

The traditional pest control market in the United States is valued at approximately \$600 million at the end-user level in 2013, based on Kline's pest management report and related file information.

- The primary pest targets are cockroaches, ants, fleas, ticks, flies, termites, bedbugs, exterior pests, and rodents.
- The primary active ingredients are fipronil, imidacloprid, diatomaceous earth, chlorfenapyr, hydramthylnon, sulfuryl fluoride, and many synthetic pyrethroids, such as cypermethrin, bifenthrin, and permethrin.
- The leading suppliers to the pest control segment are BASF, Bayer, Dow AgroSciences, FMC, Control Solutions (ADMANA), Syngenta, Central Life Sciences, MGK, AMVAC, Nisus, and many others.

Sales by biopesticide category

The pest control market utilizes two categories of biopesticide products: (1) plant extracts and (2) minerals and pheromones. Of the total biopesticide sales to the pest control segment, nearly 50%, are represented by plant extracts, mainly pyrethrin, and just over 45.1% are classified as biochemical and other pesticides, mainly orthoboric acid, while pheromones account for about 5% of the market. Based on Kline's analysis, biopesticides comprise about 6.4% of the pest control market.

Table 48: Biopesticide Sales to Pest Control in the United States by Category, End-user Level, 2016

Category	\$Thousand	% Of total
Plant extract/Botanicals	19,200	49.7
Minerals	17,400	45.1
Pheromones	2,000	5.2
Total	38,600	100.0

Biopesticide sales by active ingredient

The biopesticide portion of the pest control market totals \$38.6 million at the end-user level in 2016. Pyrethrin is the leading active ingredient with sales of \$15.2 million, or 39.4% of the segment total. Orthoboric acid is the second-leading active with sales of \$15.0 million, or 38.9% of the total, followed by essential oils with 8.8%.

Table 49: Pest Management Market Biopesticide Sales in the United States by Active, End-user Level, 2016

Active	Brand(s)	\$ Thousand	% Of total
Pyrethrin	Safer, Pyrenyl, Exciter, EcoPCO, Ultracide, ULB BP-300, ULD-BP-100, Shockwave, Riptide, Pystol, Pyroicide, Pyrethrum TR, Pyreth-IT, PT-565 Plus, PCO Control TR, Kicker, Drione, Clear Zone, CB-80, CB-40, Evergreen, Micorcare, CB PCO Fogger	15,200	39.4
Orthoboric acid	Terro, Advance, Niban, Motherearth, Drax, DEkko, Borid Acid, Boractin, Nilbor, Cymex, Bora Care, Timbor, Gourmet, Intice	15,000	38.9
Essential oil (25-b)	Eco exempt, Eco PCO, Ecovio, Proverde	3,800	9.8
Diatomaceous earth	Motherearth D Pest Control Dust	2,400	6.2
Pheromones	Indian meal moth, Confused flour moth	2,000	5.2
Cedar oil	Topia	200	0.5
Total		38,600	100.0

Sales by company

BASF is the leading company in sales of biopesticides to the pest control sector with sales of \$10.3 million, or 26.7% of the market segment. BASF markets several brands to the sector, based mainly on pyrethrin, but also based on orthoboric acid and silica gel powder. Nissus is the second-leading supplier to this sector, with sales based on orthoboric acid of \$9.0 million, or 23.3%, followed by FMC and Rockwell Labs with 11.7% each.

Table 50: Pest Control Biopesticide Sales in the United States by Supplier, 2016

Supplier	Brand(s)	\$ Thousand	% Of total
BASF	Motherearth, Ultracide, Advance, ULD BP, Pyrethrum TR, PT0565, Pro Control, P.I. Contact, ClearZone, Microcare, Tri-Die, and others	10,300	26.7
Nissus	Terro PCO, Nilban, Nibor, Cymex, Bora Care, Timbor, Web Out, and others	9,000	23.3
FMC	Drax, Borid, Topia, Purge, CB-40, CB-80	4,500	11.7
Rockwell Labs	Intice, Boractin, others	4,500	11.7
Envincio	ECO exempt, ECO PCO, Exciter	3,100	8.0
Bayer	Kicker, Drione	3,000	7.8
Insect Unlimited	Indian Meal Moth, Confused flour beetle	1,000	2.6
Trece	Cidetrack	1,000	2.6
MGK	Shockwave, Pyroicide, Evergreen, others	300	0.7
All other	-	2,200	5.7
Total		38,600	100.0

MOSQUITO CONTROL

There are around 200 different species of mosquito in the United States. Virtually all species are blood-sucking and have been found to transmit many different viruses which affect humans and livestock. Forty-three of these species are known to transmit West Nile Virus, which is of the greatest concern in the United States for humans and horses, but there are outbreaks of other diseases caused by viruses such as Eastern Equine Encephalitis, Chikungunya (found as close as Puerto Rico), and protozoa (malaria causing occasional outbreaks in the United States). There is also concern that other mosquito diseases may eventually make their way to the United States, such as Rift Valley Fever, which is particularly serious in cattle and Zika virus which has shown up in Miami.

While the possibility of being infected with a virus is clearly a concern, the major reason that mosquitoes are disliked is because of their bites. Mosquito bites are caused by female mosquitoes feeding on blood. Female mosquitoes have a mouthpart made to pierce skin and siphon off blood. Males lack this blood-sucking ability because they do not produce eggs and have no need for protein in the blood. As the mosquito is filling itself with blood, it injects saliva into the skin, which contains proteins that trigger a mild immune system reaction which causes the characteristic itching and swelling.

Females require a blood meal from humans and animals before they can lay any eggs. These are laid in water, such as in a ditch, small pool, swamp, or a container with water in it. The larvae live in water and come to the surface to breathe. After the fourth molt, the pupa is formed, and eventually the adult emerges for the cycle to be repeated.

It has been found that a relatively small area of water can sustain mosquitoes, which can infect a very wide surrounding area. Consequently, this points to the value of treating breeding areas.

Methods of control

- Chemicals or biopesticides are directed at controlling the larvae during the water stage by surface films or oils and killing the adults.
- Use of introduced natural predators is another option.

Mechanical methods that drain, fill in, or eliminate water sources that allow mosquito breeding are also used.

This report will focus on the use of biopesticides.

Current products

Over 86 products are currently available for mosquito control, focused on the larvae and adults as the pupa is impervious to pesticides. *Bacillus thuringiensis israelensis* and *Bt sphaericus* provide widely used products to control the larvae. These products are highly specific and desirable because they do not affect other insects. The products are available as liquid concentrates, granular, and dusts. Other actives include the IGR methoprene (such as Altosid), spinosad (such as Natular 2EC), and temephos granules (Skeeter Abate).

Pyrethrins and synthetic pyrethroids are effective on mosquito adults, and the spraying of the affected areas should be carried out when threshold levels are reached. One new use of pyrethroids are house gutter-based misting systems that have become popular in the southeast.

There have been no indications yet of resistance developing to Bti even though the product has been used since commercialization started in 1983.

Control can also be achieved by modifying the environment, so that standing water is less likely to occur.

The mosquito fish, *Gambusia affinis*, is a small fish native to the freshwaters of eastern and southern United States which feeds on mosquito larvae, but is also a vicious predator of other fish, and capable of disturbing the equilibrium of new ecosystems. A wide range of other biological control approaches have been taken, such as use of birds, bats, dragonflies, and frogs, but it has been shown that they do not provide adequate control.

Application

Most of the mosquito control is carried out by mosquito abatement agencies operated by local municipalities. They are funded by local tax dollars. Treatment is carried out when mosquito populations reach threshold levels which are not standardized, but based on the local situation: potential for disease, political environment, etc.

Recently, there has been decreasing use of petroleum distillates or isostearyl alcohol, as these surface oils may adversely affect ecologically sensitive areas. Lightweight paraffin- and alcohol-based surface films are more popular as they degrade much faster and are less harmful to the environment.

However, house based mosquito misting systems are installed and maintained by pest control operators.

Current market

It is estimated that mosquito control costs around \$175 million each year. This only covers the expenditure of the local abatement agencies and not the cost of homeowner OTC purchased mosquito control products. A survey carried out by the American Mosquito Association estimated that total costs in 1999 were \$240 million, but it was admitted this was limited in coverage.

Actual product sales of insecticides for mosquito control are estimated at \$85.9 million at the end-user level. Sales can be divided into five main groups:

- Adulticides – primarily organophosphates such as naled, which have been on the decline, and synthetic pyrethroids, which have been increasingly used
- Biological larvicides such as *Bacillus thuringiensis* var *israelensis* (Bti) and *Bacillus sphaericus* (Bs)
- IGR insecticides such as methoprene, which is actually classified by EPA as a chemical biopesticide
- Chemical larvicides, such as temephos, which are being phased out
- Surface films, such as isostearyl alcohols

In total, biologicals account for \$17.0 million in sales or 38.1% of the mosquito control market in 2016.

The surface films and oils are mineral-based rather than vegetable-based, and are therefore not classified as biopesticides. Currently, biopesticides represent 36.2% of total mosquito sales, 20.0% if the biologicals Bti and Bs only are considered.

Dibrom, Altosid, Vectobac, and Scourge are the leading brands. The bacillus-based biological active ingredients are important, as shown by Vectobac, Aquabac, VectoLex, and Vecto Max. The other important biological active is pyrethrin, represented by Evergreen and AquaHalt.

Products labeled for mosquito control

The two major biological products are *Bacillus thuringiensis var israelensis* (Bti) and *Bacillus sphaericus* (Bs), and there are 87 Bti products as of 2016. These products are sold in every possible formulation by a wide variety of companies, including Advanced Microbiologies, Amvac, Arysta Life Science, Bayer Environmental Science, Becker Microbials Products, Bonide Products, B2E Microbials, Clarke Mosquito Control Products, Ecosmart Technologies, Fourstar, Gowan, Helena, Loveland Products, McLaughlin Gormley King, Prentiss Inc., Spartan Chemicals, Summit Chemical Co., Valent BioScience, and Wellmark International.

Table 51: Sales of Insecticides for Mosquito Control in the United States by Brand, End-user Level, 2016

Insecticide	Active ingredient	\$ Thousand	% Of total value
VectoBac	<i>Bt Israelensis</i>	12,000	70.6
Teknar	<i>Bt Israelensis</i>	400	22.4
Vectolex	<i>Bt sphaericus</i>	1,100	6.5
Vectomax	<i>Bacillus sphearicus + Bt Israelensis</i>	1,000	5.9
FourStar	<i>Bt Israelensis</i>	1,000	5.9
Aquabac	<i>Bt Israelensis</i>	800	4.7
Aquabac	<i>Bt Israelensis</i>	800	4.7
Summit	<i>Bt Israelensis</i>	700	4.1
Total		17,000	100.0

SOURCE: Kline & Company's Global Mosquito Control Market, 2016 report.

The two major microbial products, *Bacillus thuringiensis israelensis* and *Bacillus sphaericus*, have been on the market since 1983 and 1991, respectively, and have properties that have allowed them to gain and retain significant market share. They are highly specific in their activity and so do not represent a hazard to humans and wildlife, particularly aquatic. No evidence has been found that Bs and Bti toxins harm aquatic organisms sharing the breeding sites of these vectors, or have an adverse effect on the environment. An advantage and disadvantage for Bti is in its limited time of mode of action, usually 24 to 48 hours, and so it must be applied at frequent intervals. Bti is effective, specific, bio-degradable, and possesses a long shelf life, but it does not recycle in the environment at levels high enough to provide significant residual activity.

Bacillus sphaericus, on the other hand, has been shown to recycle in field conditions, and exert larvicidal activity for a long period. However, the spores of *Bti* have the advantage over *Bs*, as *Bti* has a wider spectrum of activity against *Anopheles*, *Culex* and *Aedes* spp, while *Bs* is strongly species-specific, and has its effect mainly on *Culex*, to a lesser extent on *Anopheles*, and on only a few *Aedes* species.

There have been no indications that either product has resulted in the development of resistant strains of mosquitoes.

Valent has a combination of *Bti* and *Bs* under the trade name of Vectomax FC. *Bti* continues to be the most popular biological mosquito control product. Clarke's Natular spinosad is actually not considered a biopesticide even though it is derived from *Saccharopolyspora spinosa* and designated by EPA as "reduced risk." The six formulations of Natular are classified as Group 5 insecticides, the first public health larvicide in this class.

Table 52: Mosquito Biopesticides Sold in the United States with Estimated Sales Above \$200,000, 2016

Active	Brands	Supplier
<i>B. Thuringiensis israeliensis</i> + <i>B. Sphaericus</i>	Vectomax	Valent
<i>Bacillus sphaericus</i>	Vectolex	Valent
<i>Bacillus thuringiensis israelensis</i>	Aquabac	BASF
<i>Bacillus thuringiensis israelensis</i>	Vectobac	Valent
<i>Bacillus thuringiensis israelensis</i>	FourStar	Central
<i>Bacillus thuringiensis israelensis</i>	Summit	Anvac

Biopesticides sales by category

Total biopesticide sales of all mosquito control products are estimated to be \$17 million at the end-user level. Insecticidal bacteria, entirely bacillus types, account for all of the total.

Sales by active ingredient

The leading active ingredient in biological mosquito control is *Bacillus thuringiensis israelensis* (*Bti*), with sales of \$14.9 million, or nearly 88% of the market segment. *Bti* is sold as Aquabac by BASF, FourStar by Central LifeSciences, and Vectobac by Valent. Valent is by far the leader in the category. *Bacillus sphaericus* with sales of \$1.1 million or 6.5%, sold as Vectolex by Valent.

Table 53: Mosquito Biopesticide Sales in the United States by Active, End-user Level, 2015

Active	Brand(s)	\$ Thousand	% Of total
<i>Bacillus thuringiensis israelensis</i>	Aquabac, Vectobac, FourStar	14,900	87.7
<i>Bacillus sphaericus</i>	Vectolex	1,100	6.5
<i>B. thuringiensis Israeliensis + B. sphaericus</i>	Vectomax	1,000	5.9
Total		17,000	100.0

Sales by supplier

The leading supplier by far to the mosquito control biopesticide market is Valent, with sales of \$14.5 million at end-user level, or an 85.3% market share. This was helped by the merger of Valent and MGK's mosquito control sales. Central is the second-leading supplier, with sales just under 6%, followed by AMVAC and BASF and BAYER with 4.7% and 4.1%, respectively.

Table 54: Mosquito Biopesticide Sales in the United States by Supplier, 2016

Supplier	Brand(s)	\$ Thousand	% Of total
Valent (includes MGK)	Vectobac, Vectolex, Vectomax, Teknar	14,500	85.3
Central	FourStar	1,000	5.9
AMVAC	Summit	700	4.7
BASF	Aquabac	800	4.1
Total		17,000	100.0

Factors affecting use of mosquito control products

Environmental safety of the products is of paramount importance. The products are applied in populated areas where mosquitoes represent a public nuisance and potential health threat. Respondents ranked cost at the same level of importance due to the budgets available to mosquito agencies, which are restricted and subject to public review.

Since the applicators are operating in full view, it is important to be able to indicate that the product they are using is rated by EPA as "reduced risk."

The question of buying from a basic branded producer or generic company is a non-issue. This factor received the greatest number of respondents who consider it unimportant.

Adulticides versus larvicides: Current trends in product use have been in the direction of more adulticides to agency response to public demands when mosquito infestations are serious as to their lower cost. The cost of the top-selling adulticide products are all less than one dollar per treatment acre: Dibrom \$0.82, Biomist \$0.39, and Kontrol \$0.14, versus \$5.64 for Vectobac. Altosid costs \$17.00 per acre treatment.

Such per acre treatment costs may be rather meaningless if the larvicide is sufficiently effective that few if any adulticide treatments need to be made. Since mosquitoes can spread widely from a suitable hatching area, the cost to nearby areas may be minimal, but significant, if early control has not been carried out.

According to respondents, the public does seem to be recognizing the importance of larvicides, and 62.4% supported this approach, as opposed to 37.6% who supported more the use of adulticides.

According to an EPA statement from 2012, the underlying philosophy of mosquito control is based on the fact that the greatest control impact on mosquito populations will occur when they are concentrated, immobile, and accessible. This emphasis focuses on habitat management and controlling the immature stages before the mosquitoes emerge as adults. This policy reduces the need for widespread pesticide application in urban areas.

EPA and CDC recommend that professional mosquito control organizations throughout the United States continue to use IPM strategies. Both agencies recognize a legitimate and compelling need for the prudent use of space sprays, under certain circumstances, to control adult mosquitoes. This is especially true during periods of mosquito-borne disease transmission or when source reduction and larval control have failed or are not feasible.

From these statements, it is clear that larvicides are preferred, and adulticides should only be used when absolutely necessary. While larvicides represent only 4% of acre treatments, they represent 40.6% of the total value, with the remaining 59.4% being incurred for adulticides.

Regulatory activity: There is much greater activity with regard to implementing the Clean Water Act. The requirements under the final National Pollutant Discharge Elimination System (NPDES) Pesticide General Permit (PGP) for point source discharges from the application of pesticides to waters of the United States were issued in October 2011. The Agency's final PGP covers operators that apply pesticides that result in discharges from insecticides to control mosquitoes and other flying insects and for the control of other flying insect pests.

About 71.3% of respondents indicated that for both adulticide and larvicide programs the NPDES regulations had not affected either of these programs, and the remaining 28.7% indicated that both applications had been affected.

Climate and weather: The long-term impact of climate change will need to be assessed carefully as to how the higher temperatures and severe storm events will affect mosquito populations. The existence and activity of mosquitoes and mosquito-borne diseases are strongly linked to temperature. Work at the University of Arizona by researcher Paul Robbins has shown that higher temperatures will facilitate an increase in mosquito populations during the spring and fall seasons, but higher temperatures in the summer will decrease breeding habitats due to the drier environment.

Researchers have concluded that mosquito control methods will have to begin earlier and extend later into the year. Research work is evaluating the institutional arrangement of agencies and departments that are responsible for monitoring and controlling mosquitoes. These will need to be understood by any company considering the development and marketing of a mosquito control product.

Weather conditions can always create short term conditions that either favor or reduce mosquito populations. Agencies will always have to be able to respond to sudden increases.

Economic climate: Since mosquito abatement programs are funded through public funding, mainly counties with some state contributions, the overall economic situation will affect spraying budgets.

Storm water best management practices: The implementation of BMPs may result in the impounding of water which can provide breeding areas for mosquitoes. A questionnaire to storm water and mosquito agencies indicated that information was not always shared regarding the location of such areas, their maintenance, and current measures that could be taken to control mosquitoes within the BMP areas. There will be greater attention to storm water particularly as climate change brings more intense storms and rainfall events. EPA accepts that the field of storm water is constantly changing, so that there will be changes.

Opportunities for biological mosquito products

The need for mosquito control biopesticides was the top priority listed as a result of the IR-4 Workshop.

While resistance does not seem to be a potential concern for the current Bti and Bs products, there would be potential for a highly specific larvicide product that could last longer, and yet was totally safe in water for aquatic and other non-target organisms including wildlife and human beings.

Kline believes that there will be greater use of larvicides, particularly if the products demonstrate enhanced longevity and high levels of efficacy against all common mosquitoes: Anopheles, Culex, and Aedes.

The challenge with adulticides is the low cost of current products in a rather limited market. However, the ability to claim EPA registered biological will be a valuable marketing asset in this highly sensitive market.

TURFGRASS

The turf grass industry covers a wide range of different land uses from the millions of professionally managed home lawns to athletic fields, sod farms, golf courses, parks, cemeteries, roadsides and landscaped areas around offices, business parks and industrial areas. It is estimated that there are approximately 40 million acres of managed turf in the United States, resulting in the crop coming in fourth place in overall acreage after corn, soybeans, and wheat.

The general outlook for biopesticides on turf is that they are best used in combination with an IPM program that includes judicious use of traditional chemical solutions. There continues to be pressure on the turfgrass industry due to societal pressures against pesticide use, local ordinances restricting pesticide use, water shortages, water use restrictions even if it is available, and growth in artificial turf installation as an alternative to address these trends. Biopesticides can be part of the solution to the pesticide use issue, and chemical suppliers are working to position their product offerings in this direction.

Kline reports on turf management provides a figure of \$800 million for the value of product sales to control insects, weeds, fungal pathogens, and nematodes for use on professionally managed turf on lawns, parks, golf courses, sod farms, industrial and institutional grounds and highway rights of way. This excludes the cost of application by professionals.

The highest level of care is given to golf courses. It is widely acknowledged that golf greens are the most intensely treated targets for crop protection products. It has been estimated that there are over 15,800 golf courses for the 25 million golfers in the United States. The average golf course acreage is 118 acres, based on Kline's research, resulting in a total of some 1.8 million valuable acres. Most attention is given to the greens, which only represent a small percentage (about 4%) of the total area, but take up much of the attention and heavy expenditure.

IPM is considered to be common on golf courses, and it is estimated by Kline that 41% of golf courses have a formal written IPM plan. This is an indication of the increasing concern about pesticide use. Golf courses rely heavily on irrigation, particularly in arid areas, and pollution of streams and rivers with pesticide and fertilizer residues is a major concern.

Factors affecting the biopesticides market

Local climatic conditions play a critical role, so that the needs of turf in the southern regions with 12 months growth and insect, pathogen, and weed attack are different from the northern regions. For example, Dollar spot is the top pathogen problem in the Northeast and black cutworm is serious. White grubs are serious in most regions although the species differ. In Florida, mole crickets are serious in bahiagrass and other grasses, billbugs on zoysiagrass.

Biopesticides have tended not to provide fully satisfactory control, especially in high-value turf, so there is some history to overcome. A twelve-year Cornell study on Long Island found that greens managed by using low-risk biological techniques could not withstand disease infestations, and became unplayable on several occasions, whereas IPM greens almost always held acceptable quality and had 33% to 96% lower environmental impact than conventionally managed greens.

This result indicates the value of a combination program rather than trying to manage the pathogens or insects with biopesticides alone.

The intensive use of fungicides has resulted in resistant strains of pathogens to the chemical. In most situations, the need will be to meet the needs of an IPM program incorporating biopesticides wherever possible. The preventative action of microbial pesticides means early applications and either combinations or alternating spraying.

Local municipalities may already have put restrictions on chemical use, but pressures are increasing to reduce the use of traditional chemicals for insect, pathogen, and weed control in turf grass. One respondent made it clear that the handwriting is on the wall that chemical use must be reduced. There is beginning to be an acute need for effective alternative products.

Reports of contaminated water supplies get quick media coverage and local and state officials have to respond by issuing further restrictions to ensure that the problems do not occur again. Public opinion plays a critical role.

The North Carolina EPA has made it clear that polluted storm water runoff is the number one cause of water pollution, with common examples, including over fertilizing of lawns and excessive pesticide use. Golf courses will be increasingly anxious to reduce their chemical applications, while still maintaining the quality of the turf.

There is strong pressure to ban synthetic pesticides in some cities and municipalities. New York and San Francisco have restrictions, and some municipalities have banned their use. In Quebec, the province has restricted its use in public places but has had to accept that chemical pesticides are required to maintain the quality of golf courses. Ontario is requiring managers to submit programs for approval. On Long Island, the pesticide load in groundwater has required much more restricted use of pesticides. It is probably correct to conclude that there are strong pressures to reduce conventional chemical use on turf.

As water problems continue to become more widespread, the use of chemicals will be curtailed. Golf course managers are responding to the situation by being very willing to try new products, such as biopesticides, with their more favorable attributes, and will use them further when they work.

As climate change continues to reduce rainfall and increase temperatures in the Southwest and other southern states, the pressure will increase to reduce water use to ensure adequate water for human consumption. It seems very likely that irrigation for lawns, golf courses, etc. may become either unavailable or extremely expensive, so limiting the turf grass market. In fact, synthetic grass for landscape, golf, and other recreational uses has been the fastest-growing segment of the synthetic grass market.

There is greater interest in synthetic turf, but cost and current health questions over the materials used will slow growth in the short run. The Southern Nevada Water Authority considers that replacing a square foot of natural grass saves 55 gallons of irrigation water per year. Las Vegas has calculated that 99,000 gallons of water are typically used to keep 1,800 sq ft of grass green. A typical sports field requires between 500,000 to one million gallons of water in a year. It was estimated that in 2010 between 4-8 billion gallons of water were saved by converting to synthetic turf. These statistics indicate that as water becomes even less available, the irrigation/watering of natural grass will become increasingly expensive and possibly legislated against. Synthetic turf is a solution for sports fields, but home lawns are more likely to turn to mulch if water is not available at a reasonable cost.

Because of these developments, there is pressure to focus on cultural management practices, such as mowing regimes, fertilization, and general cultivation practices. Biopesticides should be able to play an increasingly useful role here.

Turf insects

Turf insects cause extensive damage to lawns, landscapes, and golf courses, amounting to hundreds of millions of dollars in economic loss. They can be divided between those that live in the soil, including root feeding white grubs (eight species of scarab beetles, including Japanese beetles), mole crickets, wireworms and billbugs (*Sphenophorus parvulus*). Thatch inhabiting insects include chinch bugs, such as *Blissus leucopterus*, sod webworms, cutworms, and armyworms. Finally, leaf insects include aphids, mites, scales, and leaf-feeding caterpillars. Ants can also be a problem, such as *Lasius neoniger* in the Northeast. Annual bluegrass weevil (*Listronotus maculcollis*) and leatherjackets (*Tipula* spp.) are becoming more of a problem.

Turf bioinsecticides

Several active ingredients are registered for the control of insects in turf. In fact, more than 200 products are registered for control of white grubs, one of the most widely distributed insect pests.

Table 55. Selected Bioinsecticides for Use on Turf in the United States, 2016

Active	Trade name(s)	Target insects	Company
<i>Bacillus thuringiensis</i>	Dipel and others	Caterpillars	Many
<i>Bacillus thuringiensis galleriae</i>	grubGONE G	Turf grubs	Phyllom
<i>Beauveria bassiana</i>	BotaniGard W22	White grubs	BioWorks, Laverlam
<i>Chromobacterium substugae</i>	Grandevo	Chinch bugs, white grubs, webworms, and others	Engage Agro/Marrone
<i>Metarhizium anisopliae</i> F52	MeT 52 ec	Sucking insects and ticks	Novozymes

Nosema locustae is a single-celled microsporidium protozoan and is labeled for the control of grasshoppers (*Melanoplus* species), locusts and mormon crickets. Biocontrol of mole crickets can be achieved by using the predacious nematodes, *Steinernema riobravus* and *S. scapterisci*.

Canadian Pest Management Centre listed European chafer, Japanese beetle, and June beetle grubs as important targets for the new biopesticides based on *Bacillus thuringiensis galleriae* (grubGONE) from Phyllom. The product was launched in the US in 2014.

Turf diseases

Climate influences pathogen distribution and disease development. Dollar Spot (*Sclerotinia homoeocarpa*) is ubiquitous and generally considered to be the most important disease. Fungicides are usually applied every seven to ten days. Brown Patch (*Rhizoctonia solani*), Pythium Blight (*Pythium aphanidermatum*) and Summer Patch (*Magnaporthe poae*) also occur widely.

Turf biofungicides

A very wide range of conventional fungicides are labeled for control of the major diseases. Pathogen resistance to some of the fungicides, such as benzimidazoles and DMIs, has occurred, but the wide range of labeled fungicides still provides good choices. These products currently have minor sales, but may increase in the near future.

EcoGuard *Bacillus licheniformis* was found to outperform standard fungicides when mixed with conventional products or alternated on Bermuda grass and creeping bentgrass. It has been shown that the combination of fungicides does not improve performance contrary to traditional thinking, except in a few cases. However, many fungicide products are combinations of fungicides with different modes of action, and the results with EcoGuard would indicate that the combination of conventional fungicide + biofungicide is a sound approach.

Table 56: Selected Biofungicides for Use on Turf in the United States, 2016

Active	Trade name	Target	Company
FUNGI			
Trichoderma harzianum Rifai strain T-22 and Trichoderma virens strain G-41	TurfShield PLUS	Soil pathogens	BioWorks
<i>Gliricladium catenulatum</i>	Primastop	Soil fungal pathogens	AgBio Inc.
<i>Pseudomonas aureofaciens</i>	SpotLess	Soil fungal pathogens	-
<i>Streptomyces lydicus</i>	Actinovate	Foliar and soil pathogens	Novozymes
BACTERIA			
<i>Bacillus subtilis</i> QST 713	Companion, Sonnet, Rhapsody	Many plant diseases	Bayer
<i>B.subtilis</i> GB03	Companion	Soil and folia diseases	Growth Products
<i>Bacillus licheniformis</i> SB 3086	Ecoguard	Dollar Spot, anthracnose	Novozymes
<i>Reynoutria sachalinensis</i>	Regalia	Plant health and range of diseases	Marrone, EngageAgro
<i>Typhula phacorrhiza</i>	-	<i>Typhula incarnata</i> and snow molds	Agrium Advanced Technologies
PLANT EXTRACTS			
Thyme oil	Promax	Fungal diseases	BioHuma Nectics
Thyme oil	Proud3	Fungal diseases	BioHuma Nectics
Garlic oil	Garlic Barrier	Brown spot +	Garlic Research Labs
<i>Reynoutria sachalinensis</i>	Regalia PTO	Fungal and bacterial diseases	Marrone

There are variable reports of the successful use of biopesticides in turf. The consensus seems to be that current biopesticide products are largely preventive in action and should be used in low to moderate infestations. The combination of biopesticide with conventional chemical, ideally at lower than normal rate, offers the best prospect for wider use of biopesticides for disease control in turf in view of the pressure to reduce chemicals.

Turf nematodes are also serious, particularly in Florida and Southern states, where the climatic and soil conditions are particularly favorable.

Turf nematicides

Fumigants have been the traditional products used to control nematodes and other insects and fungal pathogens. Methyl bromide is no longer available for this use, and it is likely that the remaining fumigants will be regulated out in the coming years.

Telone 1,3-dichloropropene is still recommended as a fumigant for application prior to sowing greens or sports fields if nematode threshold numbers warrant treatment. Abamectin is recommended for use on golf greens only. NemaCur fenamiphos has been withdrawn from sales but stocks may still be available. MultiGard Protect furfural is a more recent addition to the nematode control armory.

Various biopesticides are registered for nematode control, such as DiTera, but Neo-Tec is not EPA-registered, but instead labeled for nematode control on golf courses, sports, and recreational turf. These products currently have minor sales, but may increase in the near future.

Table 57: Selected Biopesticides Labelled for Nematode Control on Turf in the United States, 2016

Active substance	Product name	Company
<i>Bacillus firmus</i> I-1582	Nortica	Bayer
<i>Myrothecium verrucaria</i>	DiTera	Valent
<i>Quillaja saponaria</i> extracts	NemaQ	Monterey Resources
<i>Pasteuria usgae</i> B11	Econem	Pasteuria (Syngenta)
Sesame oil	Neo-Tec	Brandt

Soil Technologies Corp. claims good results with its Armorex, which consists of four natural products, including saponins from *Quillaja saponaria*. Monterey AgResources markets the active substances from *Quillaja* as NemaQ, which was launched in 2006 with recommendations for use on turf grass.

Bayer is promoting Nortica *Bacillus firmus* I-1582, which provides root-protecting properties and so provides protection rather than nematode-killing action. The product is recommended for treatment of turf at three-month intervals, as needed for the control of nematodes. Syngenta has also launched Econem-based on *Pasteuria usgae* for the control of sting nematodes.

Turf herbicides

At present, there are no widely used bioherbicides.

In Canada, Scotts Company has been developing *Phoma macrostoma* to control a wide range of broadleaf weeds. Application has been found to be safe in Kentucky bluegrass, bent grass, fescues, brome grasses, timothy and Bermuda grass. The product is not yet commercialized.

Biopesticide sales on turf

Sales of biopesticides on turf are estimated by Kline at \$9.9 million. Microbiol products make up the leading category with \$8.2 million, or 82.8% of the total followed by plant extracts with 10.1%.

Table 58 Turf Biopesticide Sales in the United States by Category, 2016

Category	Representative brands	\$ Thousand	% Of total
Microbe	Rhapsody, Serenade, Cease, Jumpstart	8,200	82.8
Plant extract (insects)	Pyganic, Pyrellin, Pyrenone, Azad	1,000	10.1
Minerals	OSO, Tavano, Sluggo Plus, BugON-Sluggo	700	7.1
Total		9,900	100.0

Sales by active ingredient

Streptomyces lydicus is the leading active, followed by *Trichoderma harzianum* and Azadirachtin. These three actives account for nearly 93.0% of sales.

Table 59 Turf Biopesticide Sales by Active Ingredient in the United States, 2016

Active ingredient	Brand(s)	\$ Thousand	% Of total
<i>Streptomyces lydicus</i>	Actinovate	6,000	60.6
<i>Trichoderma harzianum</i>	Turf shield	2,200	22.2
Azadirachtin	Azatin, Nemazad,	1,000	10.1
Potassium bicarbonate	Armcarb, Bi-Carb, Kaligreen, Milstop, Remedy	700	7.1
Total		9,900	100.0

Sales by supplier

Valent is the leading biopesticide supplier to the turf sector with sales of \$6.0 million, followed by Bioworks, PBI Gordon, and Syngenta. Other companies include Brandt, MGK, Certis, and Webb Wright.

Table 60: Turf Biopesticide Sales in the United States by Supplier, 2016

Supplier	Brand(s)	\$ Thousand	% Of total
Valent	Actinovate, Pyganic	6,000	60.6
BioWorks	Neema Shield, Turf Shield, Remedy	2,200	22.2
PBI Gordon	Azad	1,000	10.1
Syngenta	Appear	500	5.1
All other-a		200	2.0
Total		9,900	100.0

a- Includes Brandt, Certis, and others.

Opportunities for biopesticides for use on turf grass

Pressure is building to reduce the use of chemicals or synthetics on turf grass. This is greatest in public areas, sports turf, and golf courses, where the use has been high due to the high-quality turf required. This pressure is particularly high in areas with groundwater concerns, as on Long Island.

There was understanding amongst respondents that current fungicide biopesticides cannot be used on their own. As they are not curative, they must be used preventively in programs, particularly when high-quality turf is required. There seemed to be some agreement that combinations with conventional fungicides products were better than alternating biopesticides and conventional fungicides.

Local resistant pathogens may provide openings for biopesticides or to incorporate a biopesticide in to the current program to delay pathogen resistance.

Insecticide opportunities also exist to reduce the use of chemicals and due to actual insect resistance, or to delay resistance development.

Finally, there is no effective biological herbicide that can be used economically to control weeds. Such a product should ideally control a range of weeds, but dandelions are ubiquitous, and so would still be of interest.

Biopesticides for nematode control should find a valuable niche in this small but valuable market and satisfy the need for safe and effective products. Precisely timed preventive treatments using IPM could also reduce the total number of applications required, which would be desirable to the turf managers if not the suppliers. Environmental and operator safety are also important for golf course owners.

There is strong interest by golf courses and public space managers in herbicides considered to be biopesticides. Several are under development, but this report could find no examples of their availability as OTC products.

FORESTRY

Forests cover 751 million acres in the United States. 423 million acres are in private hands, and the remaining 328 million acres (44%) are public. 193 million acres are federal, and the remainder state or local forests. The federal government, USDA Forest Service, shares responsibility with state and local agents for stewardship of about 500 million acres of non-federal rural and urban forests.

Forests have been affected by many serious insect pests and pathogens which have been introduced and so have no natural predators. Forest pests are nearly impossible to directly manage because it is not economically feasible to treat forests with pesticides or fungicides.

Fire is the largest non-discretionary budgetary item, and the recent serious forest fires and reality of climate change has meant that fire now consumes 42% of the non-discretionary budget, up from 13% in 2000 and 21% in 2006.

There is a significant commercial forestry industry throughout the country, with a mixture of large national and international forestry companies producing wood for lumber and for paper. There are also many private woodland owners producing hardwood and lumber for construction work and housing.

Insect pests

There are several serious insect pests.

Southern Pine Beetle (*Dendroctonus frontalis*) is the most destructive insect pest of pine forests in the South. Large numbers of trees can be killed during the periodic outbreaks after rapid build-up of beetle populations. Average annual losses may exceed 100 million board feet of sawtimber and 20 million cubic feet of growing stock.

Gypsy Moth (*Lymantra*) has been the most serious insect pest in the eastern part of the country and there are several products available for control. In years of wet spring weather, a fungal pathogen, *Entomophaga maimaiga*, has dramatically reduced the number of gypsy moths in the eastern states. Nonstinging wasps (*Ooencyrtus kuvanae*) have also been useful at reducing gypsy moth populations by laying their eggs in moth egg masses. The larvae hatch and consume the moth eggs.

Four chemicals are allowed under the Federal Environmental Impact Statement (FEIS) that guides all publicly funded gypsy moth treatments. These four chemicals are Btk, Dimilin, Gypchek, and Mimic.

Bark Beetles have been devastating forests in all 19 Western states and Canada and decimating 88 million acres of timber at a 70% to 90% kill rate. Over 13,000 miles of power lines are being endangered with falling trees that increasingly raise the risk of fires that cause widespread problems for millions of customers.

Root diseases are considered serious particularly when linked with bark beetles as the combination can seriously affect the growth of the trees.

Western Spruce Budworm (*Choristoneura occidentalis*) does not usually kill trees but it can cause serious defoliation that may exacerbate the risk of fire. Btk can be sprayed to kill the adults but cultural methods of management are widely promoted.

Control methods

Bacillus thuringiensis kurstaki (Btk) has been widely used to protect trees from insect infestations in both rural and urban settings. The major reason that Btk has been used is because it is considered ecologically friendly and effective. However, there has been increasing criticism of its impact on other lepidopterous insects, and it has been shown to be less effective than chemicals when pest populations are extremely high, unless multiple applications are made.

It is estimated that more than one million pounds of Btk were applied each year to control gypsy moth, and 2.7 million acres were treated between 1995 and 2002 for an annual treatment of approximately 343,000 acres per year.

Dimilin inhibits molting in insects and is considered to be very effective, reported as widely used in private forests.

Nucleopolyhedrosis viruses Gypchek and TM-Biocontrol-1: A total of 54,034 acres were treated with Gypchek between 1995 and 2003, including repeated applications. Gypchek use reached almost 18,000 acres in 2005 and 2007, but dropped to less than 4,500 acres in 2011. While the registration of both these products has been maintained with EPA, there is no production or use.

Mimic is a pheromone, used to disrupt mating. Several other products, such as azadirachtin, synthetic pyrethroids, spinosad, and tebufenozide are registered. However, they are not recommended, as the potential to harm other species is too great for their widespread use.

The total cost of treatment with Btk is \$35.00 to \$40.00/acre versus \$8.00 to \$16.00 for mating disruption.

Table 61: Major Products Labeled for Use in Forestry in the United States, 2016

Active	Product	Target insect(s)
<i>Bacillus thuringiensis kurstaki</i>	Foray, DiPel	Gypsy moth and other caterpillars
Nucleopolyhedrosis virus	Gypchek	Gypsy moth
Nucleopolyhedrosis virus	TM-Biocontrol-1	Douglas fir tussock moth
Tebufenozide	Mimic (pheromone)	Gypsy moth
	Dimilin	Gypsy moth and others
Verbenone	SPLATverb Repel	Bark beetles

Forestry biopesticide sales

The only documentable sale of biopesticides on forestry is that of Bt kurstaki, sold as Foray or Dipel by Valent, valued at \$800 thousand.

Opportunities for biopesticides in the future

The U.S. Forest Service assessment of forests and prediction of losses in the future has estimated that there are 71.7 million acres of forest at risk in the coterminous United States, and a further 9.5 million acres in Alaska. This is divided between Forest Service administered forests, other federal land, and all other forest areas.

The U.S. Forest Service reports that the major problems in the continental United States are root diseases, bark beetles, and oak decline. Spruce beetle is considered to cause the most losses in Alaska. The confluence of bark beetles and root diseases has resulted in large contiguous areas at risk across much of the western United States. Emerald ash borer is rated as the most significant exotic forest pest. Tree species with the potential to lose more than 50% of their host volume include redbay and whitebark pine. This does not include factors such as browsing from ungulates, defoliation, and competition from invasive species.

According to the U.S. Forest Service, while future climate change is not modeled within NIDRM, it is expected that the climate change projected over the next 15 years will significantly increase the number of acres at risk, and will include elevated risk from already highly destructive pests, such as mountain pine beetle, and engraver beetles (*Ips* spp.).

While there are clearly serious economic implications from the figures quoted above and the projected loss in production, the reality is that the use of pesticides, including biopesticides, is almost non-existent. It is difficult to see the situation changing in the next five to ten years. Federal and state forests have become symbols of the natural environment, and as such, are not supposed to be polluted by chemicals. Environmentally acceptable products will be challenged to provide the persistence and specificity required to warrant development and marketing. Cost will also be an obvious deterrent to widespread use.

Ongoing forest projects indicate current U.S. Forest Research Service R&D efforts are underway including:

- Optimizing Gypchek and TM-biocontrol-1 for operational use
- Maximizing efficacy of Spinosad and Bt toxins for landscape treatment of Emerald Ash Borer
- Maximizing efficacy of entomopathogens for landscape treatment of hemlock woolly adelgid
- Developing herbicides for invasive plants
- Finding ways to control or deal with Mountain pine beetles in various pine species, which “may be the largest forest insect blight”

AQUATICS

The lone aquatic biopesticide identified is Zequinox, *Pseudomonas fluorescens* strain CL145A. This product is used to control zebra mussels in the Great Lakes. At this point use is limited due to limited public funding and slow adoption by manufacturing facilities where the mussels block water intakes, but this is expected to change in the future. Its sales are estimated at \$2,000 in 2016.

CONSUMER MARKET

The consumer over-the-counter (OTC) segment is by far the largest in the non-crop segment with sales of \$217.7 million, which is up 72% from our survey in 2016. This increase is partially due to the inclusion of additional 25-B products, as well as animal repellants, but also indicates the growth of this market. Pesticides are purchased by home owners and apartment dwellers for use in and around the home. This includes structural pests, lawn, landscape, and garden plots, and trees. Based on Kline's analysis, 39% of biopesticides are used for non-crop uses.

Sales of OTC products containing pesticides take place in a wide range of retail stores, from large national chains, big box stores, hardware stores, local nurseries, and increasingly via the Internet. There has been a shift over the past several years, where pesticide sales have moved from retailers, like Kmart and Sears, to home centers, like Home Depot and Lowe's. In addition, consumers are increasingly using the Internet and buying from Amazon or directly from company stores. Many of the biopesticide manufacturers now have their own Internet stores where consumers and small farmers can purchase their products. Many of the major companies offer a portfolio of products and provide retail packs of products offering control of common insects, snail and slugs, weeds and diseases.

There has been some consolidation in the consumer market, as Scotts bought Greenlight and Tom Cat, Bayer sold its Bayer Advanced line to SBM, and several new companies entered the market, including Dr. Earth, Mantis, and Maggies' Farm, all in the biopesticide category.

Products containing pesticides or bio pesticides must be approved by EPA, with the exemption of 25-B products that are exempt from registration, but in either case, each product must be labeled appropriately for the active ingredient(s), use instructions, and formulation involved.

There is considerable press and environmental organization activity denouncing use of pesticides and making significant claims regarding the adverse health effects for pets, children, and adults, resulting from the use of pesticides. The Beyond Pesticides website actively discourages the use of pesticides and recommends a range of natural remedies for pathogen and insect control.

Unlike the United Kingdom, Canada, and Belgium, where many towns have banned the use of pesticides presently, only two towns in the United States have banned all use of pesticides within their boundaries: Takoma, MD, was the first in 2013, followed in 2014 by the small town of Ogunquit, ME. An increasing number of municipalities are banning or severely restricting the use of chemical pesticides in public areas. For example, Palo Alto in California has 12 pesticide-free parks in 2014, and Bernards Township in New Jersey declared Pleasant Valley Park pesticide-free in 2009. This appears to be an acceptable balance between citizens' rights to choose to use pesticides and to prevent unintentional exposure to sensitive individuals,

OVERALL OTC MARKET

The markets for OTC products for homeowners can be broadly divided into five categories:

- Lawn and turfgrass
- Pests affecting the inside and outside of homes and apartments
- Pests affecting ornamental plants grown around and inside the home or apartment
- Mosquitoes
- Animal repellants, baits and traps

The current estimate of the total value of over-the-counter sales of insecticides at the end-user level is \$4.0 billion (Kline report, 2016). From Kline's analysis, about 5.4% of all consumer pesticides sold are biopesticides. This excludes fertilizers, traps, and rodenticides. Of this total, the segments that are most likely to be affected by biopesticides are valued at \$1.1 billion, composed of insecticides used in households, lawns and gardens, and in outdoor non-plant sites. Furthermore, about 3.9% of all consumer insecticides sold are bioinsecticides. Bioinsecticides for these uses comprise about 50% of all biopesticides used in the consumer market. The other large area of use is as animal repellents, where the market is about \$25 million and 86% are biopesticides. The use of fungicides by the consumer is much less, around \$65 million, and biofungicides comprise about 39% of this market. There are few bioherbicides, but they account for \$33.5 million in sales and about 7% of the total herbicides sold

Table 62: Traditional Consumer Insecticide OTC Market Segments in the United States with Biopesticide Activity or Potential, 2016

Segment	End-user level, \$ million		% Of total
	All	Biopesticide	
Insecticide	3,012.0	116.4	3.9
Herbicide	485.6	33.5	6.9
Rodenticides	197.0	4.0	2.0
Fungicide	65.5	25.4	38.8
All other	240.1	38.4	16.0
Total	4,000.2	217.7	5.4

SOURCE: Consumer Markets for Pesticides and Fertilizers USA, 2016, Kline & Company.

Table 63: Traditional Consumer Insecticide OTC Market Segments in the United States with Biopesticide Activity or Potential, 2016

Segment	End-user level, \$ million			% Of total
	Insecticide	Bioinsecticide	% Bioinsecticide	
Household	504.7	59	11.7	50.9
Lawn and garden	623.2	58	9.3	49.1
Total	1,028	116	11.3	100.0

SOURCE: Consumer Markets for Pesticides and Fertilizers USA, 2016, Kline & Company.

The consumer pesticide market has traditionally grown in the low single digits and is expected to grow at a rate of 2.4% over the next five years, but certain societal and environmental trends make the long-term outlook less inviting for suppliers, while others suggest opportunities for growth. Some of the issues include:

- Declining interest in home ownership and yard work among younger families
- Concern/awareness over the environmental impact of chemicals applied to homes and yards
- Delayed family formation and home ownership due to economic circumstances
- Dual spouses employed, allowing less time for gardening
- Declining use of household insecticides over the past ten years while the other consumer categories discussed here remained flat
- Water availability in certain populated areas of the United States
- EPA concerns over run-off of fertilizers and pesticides from lawn care
- New health concerns related to mosquito born Zika virus and Lyme disease from ticks
- The growing bed bug infestation
- Invasive weeds invading lawns and gardens
- Increasing damage from deer and other animals

These signs point are indicative of changes that have occurred in the market. Most pesticide sections in stores now include multiple animal repellants, several mosquito control products, and a plethora of bed bug control products have also emerged. While the long-term trend may suggest a decline in consumer pest control, new pests unexpectedly seem to appear that drive category expansion.

BROAD GROUPS OF TARGET PESTS

There are four broad groups of pests in the OTC market to which biopesticides either are or can be applied:

- Household pests, such as termites, ants, and cockroaches
- Lawn and garden animal, insect and fungal pests
- Outdoor nonplant flying and crawling insects
- Weed control

Household traditional products

There are a number of pests that are damaging to house structures and can cause health issues. Insects can cause damage to the actual structure of the house, such as carpenter ants and termites; provide health hazards by contaminating food, such as cockroaches and mice; and be of nuisance value, such as flies.

The list of insect pest is long, and includes ants, bed bugs, cockroaches, fleas, wasps, spiders, and flies. Incidence and intensity varies with the geography.

Traditional products are typically aerosol-based liquids or baits. The most popular consumer brands include Raid, Black Flag, Scotts Ortho, Combat Baits, and Bayer Advance. Purchases are typically made from discount/mass merchant outlets, such as Walmart, and home improvement centers, such as Home Depot.

Table 64: Retail Price of Selected Consumer Household and Houseplant Insecticides in the United States, 2016

Brand	Marketer	Form	Size	Retail price, \$
Ant Block	Amdro	Bait	24 oz	13.95
Bayer Advanced Carpenter Ant and Termite RTU	Bayer	Liquid	128 oz	20.97
Spectraide Termite and Carpenter Ant	Spectrum	Liquid	32 oz	19.92
Combat Source Kill Max for Large Roaches	Dial Corp	Bait	8 pack	7.98
Hot Shot Bed Bug Fogger	Spectrum Brands	Aerosol	3 pack	9.97
Hot Shot Bed Bug and Flea Powder	Spectrum Brands	Dust	8 oz	7.27
Spectrum Bug Stop	Spectrum Brands	Liquid	1 gal	5.97
Ortho Fire Ant Killer	Scotts	Bait	12 oz	10.48
Ortho Home Defense MAX Perimeter & Indoor Insect Killer RTU	Scotts	Liquid	1.33 gal	6.97
Raid Ant Baits	S.C. Johnson	Bait	2.4 oz	4.57
Raid Ant & Roach Outdoor	S.C. Johnson	Aerosol	20 oz	3.98
Terro Ant Killer	Spectrum	Bait	2 oz	4.17
Eco Logic	Liquid fence	liquid	2 qt	10.91
Seven	Spectrum Brands	liquid	1 qt	13.97
Rat-X	Corn seed International	Bait	1 lb	17.97

Lawn and garden traditional products

Lawn and garden insect pests include ants, caterpillars (including webworms, gypsy moths and tomato worms), beetles (including grubs, Japanese beetles, and tomato worms), aphids, fire ants, fleas and grasshoppers. They also include many larger animals such as slugs and snails, deer, moles and snakes. Diseases include a myriad of turf diseases affecting roots and shoots and foliar diseases of vegetables, such as tomatoes, and flowers, such as roses and include powdery mildews, rusts and black spot.

Product forms include granules, liquid concentrates, ready-to-use liquids, and aerosols. There are a number of brands of traditional lawn and garden products used by consumers, such as Ortho, Bayer Advanced, Raid, Spectracide, Eliminator, Green Light, Monterey, Eco Pro and Garden Tech.

Table 65: Products, Forms, and Retail Price Examples of Selected Consumer Outdoor Insecticides in the United States, 2016

Brand	Marketer	Form	Size	Retail price, \$
Amdro Ant Block	Central Garden & Pet	Granule	24 oz	13.97
Bayer Advanced 24 Hour Grub Killer Plus	Bayer	Granular	10.00 lb	17.99
Bayer Advanced Complete Insect Killer for Gardens RTU	Bayer	Liquid	32 fl oz	12.97
Bayer Advanced Complete Insect Killer for Lawns Ready To Spray	Bayer	Liquid	32 fl oz	12.97
Eco logic Lawn and Garden Insect Killer	EcoSmart	Liquid	32 oz	11.99
GardenTech Over 'n Out Fire Ant Killer	Central Garden & Pet	Granule	10.00 lb	14.98
GardenTech Sevin Insect Killer Concentrate	Central Garden & Pet	Liquid	32 fl oz	14.92
GrubEx	Scotts	Granular	14.35 lb	20.16
Ortho Bug-B-Gon Insect Killer Concentrate	Scotts	Liquid	32 fl oz	8.97
Ortho Bug-B-Gon MAX Insect Killer	Scotts	Granule	20.00 lb	14.97
Ortho Hornet & Wasp Killer	Scotts	Aerosol	15 oz	5.99
Neem Oil	Southern Ag	liquid	8 oz	9.43
Dr Earth Fungicide	Dr Earth	liquid	32 oz	15.73
Tom Cat Animal Repellant	Tom Cat	Liquid	1 qt	9.97

SOURCE: Survey Doylestown PA.

More relevant and serious for the OTC pesticide market, EPA has been concerned about the run-off from turf following the use of pesticides and fertilizers. It has been estimated that artificial turf eliminates the need for one billion pounds of harmful pesticides, fertilizers, fungicides, and herbicides, which are currently applied to grass.

As climate change affects rainfall patterns, particularly in the South and Southwest, it is likely that regulation and economics will reduce grass lawns and further increase the amount of synthetic turf.

A much more limited range of active ingredient products is available for the control of weeds in lawns compared to the wide range of insecticides. Herbicides are commonly included with fertilizers, so that one application provides both nutrition and weed control. Dandelions are one of the most common targets.

There may be a slight cloud on the horizon for the national chains, according to the National Gardening Association, as the survey found that 18-34-year-olds preferred their local hardware store as their preferred lawn and garden supplier (21% of sales), ahead of mass merchants (15%) and home centers (13%).

Local climate affects pest and pathogen incidence. A survey in Puget Sound, WA, found that more than half the residents interviewed had completed one or more pesticide applications in the previous 12 months, and over 70% to 80% were carried out by family members. Self-applying consumers were comfortable applying products themselves, did not have any serious pest problems, and found the use of a pesticide applicator to be cost-prohibitive. About 38% preferred dry RTU, versus 30% for liquid concentrates, and 27% for liquid RTU. The least popular is a dry formulation that has to be mixed with water.

Sulfur, copper, and tebuconazole are the most widely used fungicides. Fungal pathogens are particularly important in the Northwest region with its mild, wet climate. Serenade *Bacillus subtilis* QST 713 is one of the few biopesticides listed in the survey used for broad-spectrum pathogen control. Sulfur is also used for pathogen control.

CONSUMER ATTITUDES TOWARD BIOPESTICIDES

In 2012 and 2016, Kline surveyed 1,500 consumers regarding attitudes toward “green” products for controlling pests and diseases in and around the home. In 2012, about 10% indicate that they had purchased green insect control products during that year. This number had not changed for several years prior. However, the 2016 survey indicated that 29.1% of respondents had purchased a “green” insecticide and would continue to purchase this, indicating a marked change in attitude.

There is still a low level of knowledge about “green” insecticides as almost two-thirds of respondents claimed that they did not know much about them. Only 1.2% cited that they do not work well and 2.4% commented that they cost too much. Clearly, more consumers are finding “green insecticides” effective and have accepted them.

Table 66: Consumer Attitudes About “Green” Insecticides, 2016

Problem	% Of respondents
I do not know much about them, but may try them in the next 12 months	60.3
I like them and will continue to use more of them during the next 12 months	18.2
I like them and will continue to use some of them in the next 12 months	10.9
They are okay, but I prefer traditional pesticides	6.1
I do not like them because they cost too much	2.4
I do not like them because they do not work very well	1.2

NOTE: Sample size is 330 respondents.

Factors that are important to consumers when deciding to purchase a biopesticide include “safety for me and my family”, safe to the environment, and proven effective. In other words, they have to work, and be safe. What the product is made from, whether it is EPA registered, or degrades in sunlight is of less importance than safety.

Table 67: Importance of Various Purchase Factors in Buying Biopesticides by Consumers, 2016

Important purchase factors	% Rating very important or important
Safe to me and my family	85.1
Safe to the environment	81.5
Proven effective	71.5
Made with natural ingredients	68.5
EPA registered	60.3
Degrades quickly in sunlight	47.1
Recognized brand	46.8
Made with essential oils	41.5
Made with botanical pyrethrum	40.3

SOURCE: Kline & Company Consumer Survey.

BIOPESTICIDES: INSECTICIDES

Sucking and chewing insects are found on garden plants, vegetables, and house plants. Mosquitoes are a separate category requiring specific properties, which are covered in the Non-crop chapter of this report.

There has been a higher level of toxicity attached to insecticides; in a 10-year survey in New York between 1998-2007, it was found that 65% of pesticide poisonings took place in private residences. Around 40.3% of the poisoning cases reported were due to insecticides, 2.4% from fungicides, 2.5% from insecticides and another component, 2.1% from insect repellent, 1.0% from insect growth regulators, and only 0.1% for an insecticide plus herbicide. The remaining percentages involved those incidents in which the specific product was not specified. About 75% of the reports involved insecticides when the products were clearly identified.

Insecticides used in OTC products can be based on microbial, botanical, and mineral products. There are more biopesticide insecticide products than any other group.

Safety is critical for insecticides applied around the home. Organophosphate insecticides including Lindane, Diazinon, and Dursban are no longer on the market, replaced primarily by pyrethroids like bifenthrin and permethrin.

An example of a survey carried out to understand the range of OTC insecticides available in stores was conducted in Doylestown/PA area stores during the period August 5 to 9, 2017. There were 396 products. 31.6% of the products encountered on shelves contained pyrethroids, and an additional 12% included pyrethrins. Various “oils” (mineral, vegetable, essential) were found in 19.6% of the products, neonicotinoid insecticides in 3.2%, and 5.6% included soaps. In 2012, about 10% of the products encountered contained neonicotinoids. This reduction may be due to consumer awareness of the issues concerning neonicotinoids and bees. Several companies also offer food grade diatomaceous earth to control a wide range of insect pests by applying the dust on to plant foliage: vegetables, fruit, and ornamentals.

Pyrethroids had also dominated the survey carried out in 2008. Scotts announced that it is phasing neonicotinoids out of its product line due to concerns about bee toxicity.

A few major types of bioinsecticides account for nearly 70% of the biopesticides sold to consumers in the U.S. market.

Table 68: Selected Microbial and Biochemical Biopesticides Used in OTC Insect Control Products in the United States, 2016

Active	Trade name(s)	Supplier name	Target pest(s)
BIOLOGICAL			
<i>Bacillus thuringiensis kurstaki</i>	Dipel, Thuricide	Various	Caterpillars
<i>Bacillus thuringiensis israelensis</i>		Various	Flies
<i>Nosema locustae</i>	NOLO Bait	M&R Durango	Japanese beetles
Capsaicin	Hot Pepper	Bonide	Insect repellent
PLANT EXTRACTS/OTHER			
Neem oil	70% Neem oil, Rose - defence	Bonide, Green Light, others	Mites
Azadirachtin	Bio-neem	Bonide, Greenlight	Chewing and sucking insects
Pyrethrins	Many trade names	Various	Contact insecticide
Rosemary Oil	Spider killer	Envincio	Spiders
Vegetable oils	Bonide, Ortho, Ecosmart, Garden-Tech	Bonide, Ortho, Ecosmart, Garden-Tech	Contact insecticide
MINERALS			
Diatomaceous earth	Several	Concern, St Gabriel's	Desiccant for soft bodied insects
Sodium tetraborate decahydrate	Terro Bait	Woodstream	Ants
Iron Phosphate	Slug and Snail Killer	Scotts	Snails

BIOPESTICIDES: FUNGICIDES

There are several diseases which affect lawns, vegetables, flowers, and trees in the garden. Diseases particularly for roses, probably the most widely treated plant, include Black Spot, Powdery Mildew, Botrytis, and Rust. There are a few microbial pesticides that are widely used in OTC products for the control of various plant diseases, except for Serenade, *Bacillus subtilis* QST 713. Actinovate are commonly used chemical fungicides which include azoxystrobin, myclobutanil, propiconazole, and triadimefon.

Much more common are biopesticides based on minerals. Several companies, such as Bonide, sell products based on potassium carbonate and labeled for control of powdery mildew. Products include Remedy, Kaligreen, and Bi-Carb Old-Fashioned Fungicide. Similarly, biofungicides based on copper and sulfur are commonly sold in the consumer market.

The primary traditional fungicide brands are Ortho, the leader by far, Scott's Lawn Fungus Control, Bayer Advanced Fungus, and Bonide. Commonly used chemical fungicides include azoxystrobin, myclobutanil, propiconazole, and triadimefon. The product forms are varied, with liquid concentrates the most often used, followed by equal incidence of aerosol sprays, granules, and ready-to-use. The outlets where fungicides are purchased is somewhat more varied than insecticides, with home improvement and discount/mass outlets again leading the way, but with more involvement from lawn and garden centers, hardware stores, and farm supply outlets. This is most likely due to the difficulty consumers face in identifying the disease and then deciding how to treat it. Smaller outlets likely offer more advice and a broader range of products than mega stores.

Table 69: Retail Price of Selected Consumer Fungicides in the United States, 2016

Brand	Marketer	Form	Size	Retail price, \$
Bayer Advance Fungus Control for Lawns	Bayer	Liquid	10 lb	16.97
Bayer Advance Rose & Flower Disease Control	Bayer	Liquid	32 fl oz	15.97
Garden Safe Fungicide 3 RTU	Spectrum Brands	Liquid	24 fl oz	5.47
Garden Tech Daconil	Garden Tech	Liquid	32 fl oz	7.47
Immunox Lawn Disease Control Ready to Spray	Spectrum Brands	Liquid	32 fl oz	15.97
Lawn Fungus Control Granules	Scotts	Granular	6.75 lb	15.97
EcoSense Garden Disease Control RTU	Scotts	Liquid	24 fl oz	7.79
Ortho Garden Disease Control Concentrate	Scotts	Liquid	16 fl oz	14.97
Ortho Rosepride, Rose & Shrub Disease Control Concentrate	Spectrum Brands	Liquid	16 fl oz	13.97
Safer Garden Fungicide RTU	Woodstream	Liquid	32 fl oz	9.99

Table 70: Selected Microbial and Biochemical Biopesticides Used in OTC disease Control Products in the United States, 2016

Active	Trade name(s)	Supplier name	Target pest(s)
BIOLOGICAL			
<i>Bacillus subtilis</i> QST 713.	Serenade	Valent	Mildews
<i>Streptomyces lydicus</i> WYEC 108	Actinovate Lawn & Garden	Novozymes	Turf disease
PLANT EXTRACTS			
Neem oil	70% Neem oil, Rose defence	Bonide, Green Light, others	Powdery Mildew/ Blackspot
Jobba Oil	E-rase RTU	Brandt	Mildews
MINERALS			
Hydrated lime	Hydrated Lime	VPG	Mildews and Rust
Copper soap	Copper soap	VPB	Botrytis, Mildew
Sodium bicarbonate	Old Bi Carb	Brandt	Various
Copper hydroxide	Liquid Copper	Monterey	Mildews

BIOPESTICIDES: HERBICIDES

The most widely used herbicide across the world is Roundup, and its active ingredient, glyphosate, is widely available in a variety of OTC offerings. The contact action on any green tissue makes it an ideal product to control weeds in the absence of desirable plants, such as in driveways, paths, around fences, buildings, etc. The operator, environmental, pets, and wildlife safety of this product has been thoroughly researched. In spite of the widespread adverse publicity on the Internet, the active ingredient is widely used without any problems. 2,4-D is another widely used herbicide used by lawn care companies and owners of larger properties for the control of a range of broad-leaf weeds.

A more limited range of products is available for the control of weeds in lawns both applied pre- and post-emergence. Herbicides are commonly included with fertilizers so that one application provides both nutrition and weed control. Dandelions are one of the most common targets.

Mulch is the most popular method of controlling or suppressing weeds in plants, shrubs, and tree plantings.

There are a few organic products, and most are applied to existing vegetation, but corn gluten meal is mainly useful as a fertilizer, as well as recommended for pre-emergence weed control. It is not selective and does not control all weeds. High volumes of products are usually required to provide the desired effect, and efficacy depends heavily on the stage of growth and coverage.

Vinegar can be used for total weed control, but the actual active substance is acetic acid, and therefore not considered a biopesticide.

Table 71: Biopesticides Used to Control Weeds, Moss, or Algae in the United States,, 2016

Active	Brand(s)	Supplier
Ammoniated soap of fatty acids	Grass & Weed Killer	Bayer Advanced-Natria
Ammoniated soap of fatty acids	Herbicidal soap	Monterey Lawn and Garden Products
Ammoniated soap of fatty acids	Earth-Tone 4-in-1	Espoma
Ammoniated soap of fatty acids	Garden Safe Weed & Grass Killer	Spectrum Brands
Citric acid	Worry Free Moss & Algae	Central Garden & Pet
Citric acid + clove oil	Burn Out Weed & Grass Killer	Bonide
Citric acid, soybean oil	Organic Spot Weeder	Voluntary Purchasing Group, Inc.
Corn gluten	Concern Weed Prevention Plus	Woodstream - Safer
Corn gluten	Organic Weed Preventer Plus Lawn Food	Espoma
Corn gluten	WOW Supreme Weed Killer	Gardens Alive
Ferrous Sulfate	Moss Out	Scotts
Iron EDTA	Iron-X	Gardens Alive
Cotton gluten	Maize Weed Preventer	Bonide
Lemongrass Oil	Weed Killer	Eco Logic
Potassium soap of fatty acids	Earth-tone Moss Control	Espoma

BIOPESTICIDES: ANIMAL REPELLENTS AND RODENTICIDES

One of the fastest-growing use of consumer biopesticides has been animal repellents. Home owners are facing increased damaged to ornamental plants and vegetables caused by animal pests including deer, moles, snakes and ground hogs. These products consist of vegetable oils: usually garlic, cedar, cinnamon and castor oils, and/or putrescent eggs. Brands include Liquid Fence, Tom Cat, Bonide Repels all, and Mole max, in addition to a rodenticide made of corn gluten meal by Ecoclear (Corn seed International).

Table 72: Selected Biochemical Biopesticides Used in OTC Repellent and Animal Control Products in the United States, 2016

Active	Trade name(s)	Supplier name	Target pest(s)
PLANT EXTRACTS			
Corn Gluten meal	Rat-X, Mouse-X	Ecoclear	Rats and Mice
Castor oil	Mole and Gopher repellent	Tomcat, Molemax	Mole and Gopher
Garlic, Cedar, Cinnamon,	Snake Away	Havahart	Snakes
Peppermint, Garlic	Tom Cat repellent	Tomcat	Deer, Rabbits
Putrescent Eggs, Garlic, Thyme	Liquid Fence	Liquid fence	Deer, rabbits

BIOPESTICIDE SALES BY CATEGORY

Plant extract is the leading consumer OTC biopesticide category with sales of \$141.2 million, or 64.8% of the total. Biochemical and mineral biopesticides is the second-leading category, with sales of \$58.2 million, or 26.7%, followed by microbial and plant extract combinations, with 7.6% and 0.8%, respectively.

Table 73: Consumer OTC Biopesticide Sales in the United States, by Product Category, End-user Level, 2016

Category	\$ Million	% Of total	Examples
Botanical	141.2	64.8	Pyrethrin, neem
Mineral	58.2	26.7	Sodium bicarbonate, sulfur
Combinations	1.8	0.8	Pyrethrin/sulfur
Microbial	16.6	7.6	<i>Bt Kurstaki</i>
Total	217.7	100.0	

SALES BY ACTIVE INGREDIENT

Table 74: Consumer OTC Biopesticides Sales in the United States, by Active Ingredient, End-user Level, 2016

Active ingredient	Brands	\$ Thousand	% Of total
25-B including clove, cinnamon, rosemary, soybean, peppermint	Bonide Mite-X, Bonide mosquito beater, Brandt all natural pest control, Invincio Insect killer, St Gabriels Burn out, Havaheart Snake away, Havahart animal repellent, TomCat animal repellent, Bonide Repels all, Dr. Earth Insecticide	46,960	21.6
Pyrethrin and combinations	Ortho Elementals Garden Insect, Earth Tone Insect, Ortho Elementals 3-in-1 Rose & Flower Care, Garden Safe Fruit, Flower, & Vegetable Insect, Pyrethrin Garden Spray, Safer Flying Insect, Safer Ant & Roach Worry Free Insect Mite, Bonide Japanese Beetle, J.T. Eaton Bed Bug spray	36,700	16.8
Neem Oil and azadirachtin	Neem Concentrate, Neem II RTU, Natria Neem Oil, Garden Safe Fungicide, Safer Grub Control, Rose RX, Non-Neem II, Neem Extract	20,600	9.5
Iron Phosphate	Scotts slug and Snail Killer, Escar-Go, Corys snail bait, VPG Slu bait	15,340	7.0
Potassium salts of fatty acids	Bayer Advanced Insecticidal Soap, VPG Insecticidal Soap, Raid Flea, Ortho Elementals Insecticidal Soap, Earth-Tone Insecticidal Soap	13,500	6.2
Corn Gluten	Concern Weed Prevention, Organic Weed Preventor Plus Lawn Food, WOW Supreme Weed, Maize Weed Preventer	11,000	5.0
<i>Bacillus thuringiensis</i> -b		9,900	4.4
Sodium tetraborate decahydrate, Boric acid	Terro Ant Baits, Bulls eye ant bait, Maggies Farm ant bait	9,500	4.4
Diatomaceous earth	Crawling Insect Control, Safer Diatomaceous Earth, Victor Insectigone Flea, Safer Ant and Crawling Insect, Safer Bed Bug, J.T. Easton Bedbugs and Crawling Insect, Insect Dust	8,600	3.7
Iron HEDTA	Ortho Elementals Lawn Weed, Lawn Weed, Iron X Weed	8,000	3.7
Lemongrass oil	Eco logic herbicide, Ecologic insecticide	6,000	2.7
Copper hydroxide and	Bonide Copper dust, Monterey liquid Copper, Copper Soap	5,500	2.5
<i>Bacillus thuringiensis israelensis</i>	Mosquito Dunks, Mosquito Bits	5,500	2.5
<i>Bacillus subtilis</i>	Bayer Advanced Disease Control	3,000	1.4
Canola oil	Bayer Advanced Multi Insect Control	2,917	1.3
<i>Bacillus popilliae</i>	Milky Spore Grub Control	1,200	0.6
Citric acid + soybean oil	VPG Organic Spot Weeder	1,167	0.5
All other-c		12,300	5.6
Total		217,732	100.0

a- Pyrethrin combination sales are detailed in a separate table.

b- A minor amount of Bt Aizawa is included in the Kurstaki >100K.

c- All other includes 27 actives, including benzoic acid, capsicum, Hydrated lime, paraffinic oil, phosphite, iron phosphate + spinosad, Steinernema, and many others.

The leading ingredient group consists of 25-B product containing botanical oils, including clove, cinnamon, peppermint, and castor oil, as well as others alone and in mixtures with total sales of \$46.9 million or 21.6% of sales. This is followed by pyrethrin and pyrethrin combinations at \$36.7 million (16.8%) and neem extracts, including azadirachtin at \$20.8 million or 9.5%. All three of these categories are botanical extracts and illustrate how botanical materials have come to dominate this market.

SALES BY SUPPLIER

Scotts is the leading supplier of biopesticides to the consumer OTC market segment with sales estimated at nearly \$52 million at enduser level, including their three brands Ortho, Greenlight and TomCat, or 24.3% of the segment total. Bonide is the second-leading supplier with sales of \$31.5 million, or 14.5%, followed by Woodstream in a distant third position with sales of \$22.0 million, or 10.1%.

Table 75: Consumer OTC Biopesticide Sales in the United States, by Supplier, End-user Level, 2016

Supplier	Brands	\$ Thousand	% Of total
Scotts Ortho	Ortho Elementals Lawn Weed, Home Insect, Ant & Roach, Garden Insect, 3-in-1 Rose & Flower Care, Insecticidal soap, Slug & Snail	36,000	16.5
Scotts Greenlight	Rose Defense, Neem concentrate, Rose Defense RTU, Neem RTU	10,000	4.6
Scotts Tomcat	Animal repellent, Mole and Gopher	7,000	3.2
Bonide	Bio-Neem, Citrus Fruit & Nut Orchard Spray, Pyrethrin Garden Spray, Garden Dust, Burn Out Weed & Grass, Maize Weed Preventer, Rose RX, Japanese Beetle Killer, Tomato & Vegetable 3-in-1, Thuricide, Mite X, Hot Pepper Wax, Diatomaceous Earth, Horticultural Oil	31,500	14.5
Woodstream	Concern Weed, Victor Insectigone, Safer...Ant & Crawling Insect, Grub Killer, Bed Bug, and, Crawling Insect Killer, Bed Bug Killer, Ant & Roach Killer, Terro Ant Bait	22,000	10.1
Voluntary Purchasing Group	Insecticidal Soap, Organic spot Weeder, Crawling Insect control, Grub Control, Copper Soap	19,000	8.7
Bayer Advanced-Natria	Bayer Advanced.Home Pest control, Insect Disease & Mite, Grass & Weed, Rose Insect Disease & Mite, Lawn Weed, Multi-Insect, Insecticidal Soap, Natria Neem Oil, Slug & Snail, Fruit & Vegetable Insect, Disease, Mite	19,000	8.7
Summit Chemical	Mosquito Dunks, Mosquito Bits, Caterpillar and Webworm control, Year-Round Spray Oil	12,900	5.9
SC Johnson	Raid Flea Killer, Raid Fogger	12,000	5.5
Central Garden & Pet	Worry Free...Slug & Snail, Insecticide & Miticide RTU/Concentrate/Dust, Moss & Algae	8,700	4.0
Gardens Alive	Green Step Caterpillar control, WOW Supreme Weed Killer, Iron X Weed Killer, No-Squire Granules	6,650	3.1
Garden Safe (Spectrum)	Garden Safe... Fungicide, Neem Oil Extract, Fruit, flower & Vegetable Insect, Weed & Grass	5,500	2.5

(Continued)

Table 75: Consumer OTC Biopesticide Sales in the United States, by Supplier, End-user Level, 2016

Supplier	Brands	\$ Thousand	% Of total
Dr Earth	Weed and Grass, Insecticide	5,000	2.3
Brandt (Monterey Lawn and Garden Products)	Neem Oil, Bt, Bi-Carb Old Fashioned Fungicide, All Natural Mite & Insect, Herbicidal Soap, Horticultural Oil, 3-in-1 Garden Insect Spray, Nematode control	2,982	1.4
St. Gabriel Organics	Milky Spore Grub Control, Insect Dust, Holey Moley No More Moles, Wasp & Hornet Killer	2,250	1.0
MGK	Pyganic, Pyrellin, Pyrenone, Azera	2,725	1.3
Gowan	Aza-Direct	500	0.2
All other-a		14,025	6.4
Total		217,732	100.0

a- Includes Bioworks, Ecoclear, Organic Laboratories, Certis, Mantis, Peaceful Valley, Liquid fence, and Valent and others.

OPPORTUNITIES FOR BIOPESTICIDES IN CONSUMER OTC MARKETS

The requirements for consumer OTC products are even more stringent than for products used in commercial agriculture. These products must be simple to understand and easy to apply. Hence a lot of these products come ready to use as granules, aerosols, or have built-in sprayers. Generally, they do not need to provide control for a long period of time. However, there is need for products that provide contact and residual control, but are completely safe to applicators, children, and pets, as well as safe, if they get into storm water or groundwater.

The following opportunities are mentioned by interview respondents as potential markets for biologically-based pesticides:

- Termites
- Bed bugs
- Mosquitoes
- Selective herbicides for use in turf grass
- Pre-emergent herbicides

COMPANY PROFILES

ANDERMATT BIOCONTROL

SALES REVIEW

Andermatt Biocontrol sales are comprised of bioinsecticides, biofungicides, biostimulants/ bio-innoculants, rodent control, and macroorganisms. Its U.S. sales for the biological market are estimated at \$0.2 million in 2016.

U.S. BUSINESS HIGHLIGHTS

Andermatt successfully launched the products Helicovex and Spexit in the US market in 2015 and 2016 and established a subsidiary Andermatt USA. Andermatt Biocontrol AG (Andermatt), and Certis USA, a leading biopesticide company, entered into an agreement to develop and market new granulovirus insecticides for the NAFTA region. The companies will collaborate on the development of new generations of granulovirus products targeted for fruit production that are substantially more potent and offer broader spectrums of control than current products on the market.

COMPANY OVERVIEW

The company, Andermatt Biocontrol, was founded by Dr. Martin Andermatt and Dr. Isabel Andermatt in 1988. Since then, it has developed to become the leading company in Switzerland for biological based plant protection.

The key expertise of Andermatt Biocontrol AG is the production of baculoviruses and entomopathogenic nematodes, as well as beneficial insects for greenhouses and stored products.

At present, Andermatt Biocontrol AG has about 80 employees working in Research and Development, Production, Logistics, Marketing and Administration. Globally, the company markets its manufactured products plus selected high-quality trade products, through more than 80 distributors.

Andermatt Biocontrol has subsidiaries in France, South Africa, Brazil and Canada.

PRODUCT LINE ANALYSIS

Andermatt offers two insect virus products in the United States, targeting row crops and vegetables.

Table 76: ANdermatt Biocontrol Product Line for Crop Markets in the United States, 2016, End-user Level

Major brand	Active ingredient	\$ Million	Target markets
Helicovex	Helicoverpa armigera nucleopolyhedrovirus (HearNPV)	0.1	Corn, cotton
Spexit	Spodoptera exigua nucleopolyhedrovirus (SeNPV)	0.1	Greenhouse, vegetables
Total		0.2	

ADVANCED BIOLOGICAL MARKETING (ABM)

SALES REVIEW

Advanced Biological Marketing's (ABM) biopesticide sales are comprised of seed inoculants. Sales were estimated at \$4.7 million in 2013, increasing to \$5.0 million in 2014 and \$8.0 million in 2016.

U.S. BUSINESS HIGHLIGHTS

U.S. crop protection sales for Advanced Biological Marketing (ABM) increase 60% during 2016 to \$8.0 million. Growth is driven mainly by its Marauder product.

Established in 2000, ABM provides biological seed treatments for commercial agriculture that increases a crop's potential and yield. Its product line includes biological seed enhancements, mainly inoculants, for corn, soybeans, wheat, and many other production crops. The company's headquarters are in Van Wert, OH.

ABM has introduced a new product to the U.S. seed industry each year since 2008.

In 2013, the company files patents with the U.S. Patent and Trademark Office (USPTO) to develop organic microbial encoding, or a biological barcode, for the tracking of produce from the farm to customers' tables. The food safety tracking system will initially track melons, tomatoes and leafy greens.

In 2014, ABM announces the issuance of a U.S. patent for a Trichoderma strain that induces resistance to plant diseases and increases plant growth. Trichoderma is a genus of fungi that is present in all soils, where they are the most prevalent culturable fungi. The company markets this new technology under its iGET name, which stands for Induced Gene Expression Triggers Technology.

OWNERSHIP STRUCTURE

ABM was founded by farmers, agronomists, and agricultural consultants in 2000 and has a private ownership structure.

ACQUISITIONS

In December 2013, ABM purchases the assets of BioSolutions, an importer of innovative agricultural technologies in Southern Africa. The acquisition includes the office in Litchenburg South Africa, a manufacturing facility and a distributor network. ABM branded products will be produced, formulated, and packaged at the location. The facility in Litchenburg will manufacture products for the entire African Continent, Southeast Asia, and Australia.

LICENSE/RESEARCH/MARKETING AGREEMENTS

In May 2014, the company announces its partnership Summer Intern Program with The Ohio State University and University of North Carolina at Greensboro. Interns support ABM's expansion in international markets, focusing primarily on Africa, through market research, international order processing, and the completion of export documentation, as well as engaging in customer support for international buyers.

In May 2014, ABM announces an agreement with INCOTEC Group, based in Enkhuizen, The Netherlands, in which INCOTEC combines ABM's yield enhancing inoculants with INCOTEC's innovative seed coating and enhancement technologies. INCOTEC has marketing rights to the seed industry of ABM products in the United States, Europe, India, and South America.

R&D

Most of the company's technologies have been developed by Dr. Gary Harman while he was a professor at the NY State Agricultural Experiment Station. ABM has funded and benefited from Dr. Harman's research since the start of the company in 2000.

In September 2013, ABM announces the groundbreaking for its new R&D facility in Geneva, NY. The Geneva laboratory is the location of the company's new R&D facility, moving from its Cornell University location. Construction will be for a new greenhouse space for the operation. The cost of renovation, construction, and equipping the facility is expected to exceed \$1 million and it will initially be staffed by six persons, and three of them hold of PhD degrees. Staffing is expected to increase over the next few years to more than 10 persons, and will also incorporate the services of research consultants and cooperators from around the world.

U.S. SALES

AMB's U.S. sales for the crop protection markets total \$8.0 million in 2016. ABM currently has no non-crop biopesticide sales.

PRODUCT LINE ANALYSIS

Inoculants

Most of ABM's inoculant product lines' tank-mix is compatible with certain seed treatments and can be co-applied several days prior to planting. Because the inoculants contain a living organism, some seed applied chemicals may be harmful to inoculant bacteria, so it is important for the applicator to check compatibility on the product label before use.

The SA designation within several of ABM's products contains its iGET technology.

ABM's inoculants are marketed for use in commercial seed treatment systems.

MegaPack for soybeans is a low-volume liquid formulation that drastically reduces seed bridging and sticking.

Field crops

The company's portfolio of inoculants targets primarily the large field crops of corn and soybeans, but also covers:

- Wheat/cereals
- Vegetables
- Peanuts
- Alfalfa
- Cotton
- Dry beans
- Cover crops, including peas, lentils, vetches, and faba beans

The company's SabrEx root inoculant is currently its leading selling product. SabrEx contains ABM's iGET Technology package, which is a unique formulation of two carefully selected biological fungi strains called Trichoderma.

Specialty crops

AMB has one product, Naturall, which is a root inoculant labeled for use within the specialty vegetable markets.

The company markets Naturall as:

- Enhanced root growth
- Increased seedling vigor
- Higher yields
- Improved nutrient and water efficiency

Table 77: ABM Biopesticide Inoculant Product Line for Crop Markets in the United States, End-user Level, 2016

Major brand	Active ingredient	\$ Million	Target markets
SabrEx, Biocure, Naturall	Trichoderma	3.0	Corn, cotton
Excalibre, Excalibre-SA	Powdered Cellulose, Rhizobia Bacteria	a	Soybeans
Graph-Ex, Graph-Ex SA	Talc, Graphite, Soybean Inoculant	a	Soybeans, peanuts, alfalfa/clover, dry beans
Marauder	Rhizobia, Bacillus, LCO	5.0	Soybeans
MegaPack	Rhizobia	a	Soybeans
America's Best Inoculant	Rhizobia	a	Soybeans, peanuts, peas/lentils
Total		8.0	
a- Inoculants are excluded from this biopesticide report except in cases where the inoculant also makes a pesticidal claim.			

U.S. BUSINESS REVIEW

U.S. organizational structure

ABM has an established sales and marketing structure for selling its products.

The company has one National Sales Manager with six sales representatives covering the entire United States. It has hired experienced sales representatives within the agricultural industry, specifically individuals with prior seed treatment knowledge. It appears that many of the company's employees play various roles as is typical within a company of this size.

Product management strategies

ABM's core strategy is to develop products through its R&D efforts. The company's newly built R&D facility is located in Geneva, NY.

The company recently announced the development of a food safety tracking system, which likely indicates the company's broad strategy and ability to identify market trends outside of its core inoculant business.

ABM has experience in obtaining and filing with the U.S. Patent and Trademark Office (USPTO).

Marketing and sales programs

ABM maintains a basic strategy of marketing to major distributors, as well as the large ag retailer and smaller farm retail outlets.

MANUFACTURING

AMB's products are manufactured in-house in Van Wert, OH.

The company is also gearing up its South Africa division to do manufacturing as well for foreign markets.

BASF

SALES REVIEW

Table 78: BASF Sales Summary, 2014 to 2016

	\$ Million		
	2014	2016	Change, %
GLOBAL SALES SUMMARY			
Corporate global	98,537	63,671	(35.4)
Corporate U.S.	13,795	8,978	(34.9)
Global crop protection	7,157	4,139	(42.2)
Global seed	-	-	-
U.S. CROP PROTECTION CHEMICALS			
Crop Markets	670	746	11.3
Professional Markets	180	160	(11.1)
Seed Treatments	10	9	(10)
Total	860	915	6.4
U.S. BIOPESTICIDE SALES			
Biopesticides	13.8	13.3	(3.6)
Seed Inoculants	4.5	41	811
Total	18.3	54.3	197

U.S. BUSINESS HIGHLIGHTS

BASF's U.S. biopesticide sales, including seed inoculants, grew 197% during 2016 to \$54.3 million. Growth is due to its seed inoculants. Some of this growth may be due to the inability to separate the values of rhizobia and biopesticides.

BASF gained entry into the biopesticide market through its acquisition of Iowa-based Becker Underwood (BU) in 2012. The company purchased BU for \$1.02 billion from Norwest Private Equity. In October 2013, BASF concluded the structural integration of the BU business. As a result, the Functional Crop Care global business unit was established which integrated BU's product line.

The new Functional Crop Care business is organized under the company's Agricultural Solutions Business, which includes:

- Herbicides
- Insecticides
- Fungicides
- Plant growth regulators
- Seed treatment
- Functional crop care

BASF's Functional Crop Care business focuses on three areas of biological innovation:

- Soil Management: products to improve nitrogen management and products to optimize distribution of water in the soil
- Seed Solutions: biological seed treatments, inoculants, polymers, and colorants
- Crop Care: biological control products, biological and conventional Plant Health products, and plant growth regulators

In 2016, BASF's global Functional Crop Care business is estimated at \$365 million. Sales for the Functional Crop Care business in the United States in 2016 total \$95 million.

Major products focused within BASF's biopesticide portfolio include the following:

- *Bacillus subtilis*: Vault, Subtilex, HiStick
- *Steinernema carpocapsae*: Millenium, Nematac
- Pyrethrins: Ultraside, Clear zone

U.S. CROP PROTECTION BUSINESS

Business summary 2016

BASF has many products under its FCC business. However, this profile only targets products included under this report's definition of a biopesticide.

Field crop markets

The following products are seed inoculants for use in soybeans:

- HiStick
- Vault HP, PPST
- Marauder

U.S. SALES

BASF's biopesticide sales are estimated at \$54.3 million in 2016, made up of a combination of insecticides and fungicides.

Crop markets account for \$41.4 million while the greenhouse nursery accounts for \$1.1 million and the professional non-crop markets sales total \$11.8 million in 2016.

Table 79: BASF's Biopesticide Sales in the United States, 2016

Line item	\$ Million
Total crop market sales	41.4
Total Greenhouse/Nursery Sales	1.1
Total professional (non-crop) sales	11.8
Total	54.3
Estimated.	

PRODUCT LINE ANALYSIS

BASF's Biopesticide product line consists of the following products:

Table 80: BASF's Biopesticide Sales in the United States, 2016

Product	\$ Million
Vault, PPST	41.4
Ultracide, Clear zone, Microcare	8.9
Aquabac	1.5
Nematec, Nemasys, Millenium	0.9
Mother earth, Tie Die	0.4
Other	1.3
Total	54.3
Estimated.	

BASF's product line is based on principally four technologies: seed treatments based on *Bacillus subtilis* and LCO; pest control insecticides based on Pyrethrin; mosquito pest control insecticides based on *bacillus thuringiensis israelensis*; and insect control for the greenhouse nursery industry, based on beneficial nematodes. In addition, BASF maintains a collection of microbial fungicides including those based on bacillus and Trichoderma.

U.S. BUSINESS REVIEW

U.S. organizational structure

BASF's crop protection business unit is classified internally as Agricultural Solutions.

Effective January 1, 2013, the company announced it formed a newly global Functional Crop Care unit, which merged its existing research, development, and marketing activities in the areas of seed treatment, biological crop protection, plant health, as well as water and resource management, with those of Becker Underwood. Becker Underwood's animal nutrition business is integrated into BASF's Nutrition & Health division.

Table 81: BASF Biopesticide Product Sales, in the United States, End User Level, 2016

Major brand	Active ingredient	\$ Million	Target markets
Pyrethrin	Ultracide, ULD BP, PTO 565, Clear Zone, Microcare	8.9	Pest control
Subtilex	<i>Bacillus subtilis</i> MBI 600	0.5	Greenhouse crops
Auqua Bac	<i>Bacillus thuringensis</i> , <i>israeliensis</i>	1.5	Mosquito
Mother earth. Tie die	Diatomaceous earth	0.4	Pest Control
HiStick		-	Seed inoculant for soybeans
PPST, Vault HP	<i>Bacillus subtilis</i> , LCO	41.0	Growth enhancement system for soybeans
Nemasys	<i>Steinernema feltiae</i>	0.3	Nematode for control of Fungus Gnats and Western Flower Thrips in Greenhouse
Nematec	<i>Steinernema carpocapsae</i>	0.2	Operations
Millenium	<i>Steinernema carpocapsae</i>	0.2	Turf and ornamentals
Nematac		-	Cranberries
All other		1.3	Various
Total		54.3	

SUMMARY OF U.S. MARKET POSITION

BASF purchased Becker Underwood in 2012, a company from Ames, Iowa specializing among four distinct business units:

- Seed Enhancements
- Landscape Coatings
- Turf & Horticulture
- Biopesticides

The Becker Underwood (BU) acquisition effectively expanded the company's product portfolio in the areas of biological crop protection, turf and horticulture, animal nutrition and landscape colorants and coatings.

For the purposes of this report, BASF has a small footprint among biopesticide sales that is defined within the beginning chapter of this report.

The company has quickly organized BU's product portfolio under the BASF umbrella, and despite having a slow year in 2016, the company's Functional Crop Care business is well poised for growth, despite challenging market conditions.

STRATEGIC OUTLOOK TO 2021

BASF's strategy is developed on long-term market trends. The company aims for sustainable development to ensure that there is enough food for a growing world population. The ultimate goal is to increase crop yields through a long-term innovative strategy to secure the company's future growth.

The company plans to expand its R&D activities in the future, especially in North and South America. By 2020, BASF aims to conduct half its research and development activities outside of Europe in order to gain on-location access to customers and their market knowledge, as well as to talent and innovation centers.

BASF has a solid portfolio of products within its Functional Crop Care business unit along with a strong pipeline of new products that will further establish the company within the biological crop protection segment of the industry.

BAYER CROPSCIENCE

SALES REVIEW

Table 82: Bayer CropScience's Sales Summary in the United States, 2014 to 2016

	\$ Million		
	2014	2016	Change, %
GLOBAL SALES SUMMARY			
Corporate global	45,881	51,744	11.3
Corporate U.S.	9,672	12,677	31
Global crop protection	8,554	8,745	2.2
Global seed	1,220	1,294	6.0
U.S. CROP PROTECTION CHEMICALS			
Crop markets	830	1,383	66.6
Professional markets	250	277	10.8
Seed treatments	395	315	(20.2)
Total	1,475	1,975	33.9
U.S. BIOPESTICIDE SALES-a, b			
Biopesticides	177.4	150.6	9.1
a- Biopesticide sales include crop and professional markets and are stated at end-user level.			
b- Includes Bayer Advanced Natria's sales of \$32.9 million.			

U.S. BUSINESS HIGHLIGHTS

Bayer CropScience's U.S. biopesticide sales decreased 9.1% during 2016 to \$150.6 million.

U.S. crop protection chemical sales are up an estimated 8.4% in 2014, with highlights including:

- Significant increases in sales within its herbicides unit, particularly with products for use in corn
- Sales of insecticides and seed treatment also expanded, while business in the fungicides unit decreased.

Bayer CropScience (Bayer) gained entry into the biopesticide market through its acquisition of Davis, California-based biopesticide company, AgraQuest. The company purchased AgraQuest in July 2012 at a purchase price of \$425 million. At the time of acquisition, AgraQuest employed a staff of 250 full-time employees.

AgraQuest is a global supplier of biological pest management solutions based on natural microorganisms. The acquisition has allowed Bayer to build a leading technology platform for green products and to strengthen its strategically important fruits and vegetable business in addition to other crops and markets.

In 2013, the company folded the AgraQuest business and all of its products into Bayer CropScience. Bayer has organized its biopesticide product portfolio alongside its traditional crop protection chemistry products.

AGRAQUEST HISTORY

AgraQuest was formed in 1995 by Dr. Pamela Marrone after leaving Novo Nordisk subsidiary Entotech when it was sold to Abbott Laboratories. She left the company in 2006 to start another new venture, Marrone BioInnovations.

Marcus Meadows-Smith took over as AgraQuest CEO in 2008. Marcus initiated a strategy change and strengthened R&D capabilities. The company focused on designing products for conventional agriculture that were superior to the market-leading synthetic pesticides used for organic food production.

The company's growth prior to the Bayer acquisition has been organic, and the company claims to have grown by over 30% each year.

R&D

Bayer's biopesticide development capabilities rely on the company's investment in strategic areas of R&D excellence which include:

- Microbial and plant genomics
- Fermentation
- Natural product chemistry
- Nematology
- Formulation
- Microbiology

Bayer announces plans to consolidate and expand its U.S.-based R&D operations for vegetable seeds and biological crop protection products in a new site in West Sacramento, CA. The integrated site, with an existing office and laboratory building on ten acres of land, can employ approximately 300 people.

The company has a team focused solely on biopesticides, with a deep pipeline of new products poised to enter global markets over the next five years.

ACQUISITIONS/AGREEMENTS: INTERNATIONAL

In 2013, Bayer acquired Prophyta GmbH, a supplier of microbial crop protection products headquartered in Mecklenburg-Vorpommern, Germany. The acquisition gave Bayer the rights to the Prophyta's research and development laboratories as well as production and formulation facilities in Wismar, Germany.

In May 2016, Bayer sold its Bayer Advanced and Bayer Consumer brands to SBM Development. SBM Développement is an independent and family-owned France-based group of companies that develops, formulates, and distributes ranges of crop solutions for professionals and consumers. Their activity relies on three pillars: R&D, Industry, comprised of two formulation and packaging factories in France, and Distribution, with Novajardin, a unit dedicated to Consumers and offering the brands Solabiol, Capiscot, Caussade and ANTI, and CMPA, a unit dedicated to crop professionals. A leader in the French home and garden market, SBM has expertise in biologics, fertilizers, and soils. With about 300 employees in Europe, the company has grown organically and through a series of successful acquisitions. Because of the mid-year transition, we attributed all sales to Bayer.

In May 2016, Bayer also announces that Bayer and Monsanto have signed a definitive agreement under which Bayer will acquire Monsanto for USD 128 per share in an all-cash transaction. Based on Monsanto's closing share price on May 9, 2016, the day before Bayer's first written proposal to Monsanto, the offer represents a premium of 44 percent to that price. While there is resistance to completing this deal it would greatly transform the ag market.

U.S. CROP PROTECTION BUSINESS

Business summary 2016

Bayer's biopesticide profile consists of 13 products listed under five active ingredients. Sales of the Consumer business allow Bayer to focus on its professional businesses and make the proposed merger with Monsanto a better fit. Monsanto sells its Consumer brand of round-up through the Scotts company which is a fierce competitor of Bayer.

Field crop markets

The company's blockbuster biopesticide product is the Poncho/Votivo brand of nematocide seed treatment for the following list of crops:

- Corn
- Cotton
- Soybeans

Poncho/Votivo is a seed treatment that combines a chemical insecticide with a biological mode of action. Votivo lives and grows on young roots to protect corn, soybeans, and cotton plants from a variety of insects and nematodes by building a natural protective barrier around the root, which the nematodes are unable to penetrate. Poncho is an insecticide that provides a plant protection from many critical insect and nematode pests. This dual protection results in a healthier plant establishment and a more uniform crop resulting in an average yield increase of 1.5 to 2.5 bushels of soybeans per acre.

U.S. BIOPESTICIDE SALES

Table 83: Bayer CropScience's Biopesticide Sales in the United States, End-user Level, 2016

Line item	\$ Million
Total crop market sales	143.7
Consumer sales-a	4.2
Total professional (non-crop) sales	2.7
Total	150.6
a- Bayer's Consumer business was sold to SBM Development Group in 2016. Estimated.	

Table 84: Bayer CropScience's Biopesticide Sales Summary in the United States by Crop Market, End-user Level, 2014 and 2016

Product group	\$ Million-a		Change	% Change
	2014	2016		
Herbicides	7.4	0	(7.4)	(100.0)
Insecticides	18.7	4.5	(14.2)	(75.9)
Fungicides	19.6	12.5	(7.1)	(36.2)
Seed treatments	125.0	130.0	5.0	4.0
All other	6.7	3.6	(3.1)	(46.0)
Total	177.4	150.6	(26.8)	(15.1)

a- Includes Bayer Advance Natria's product sales and Bayer CropScience's sales.

PRODUCT LINE ANALYSIS

Bayer's Biopesticide product line consists of various products:

Table 85: Bayer CropScience's Biopesticide Product Sales in the United States, End-user Level, 2014

Major brand	Active ingredient	\$ Million	Target markets
Votivo (mix w/Poncho)	<i>Bacillus firmus</i>	130.0	Corn, cotton, soy
Rhapsody	<i>Bacillus subtilis</i>	5.0	Fruits and vegetables, ornamentals, turf
Serenade	<i>Bacillus subtilis</i>	3.0	Fruits and vegetables, grains, corn
Serenade Max	<i>Bacillus subtilis</i>	0.5	Fruits and vegetables, grains, corn
Serenade Soil	<i>Bacillus subtilis</i>	2.0	Fruits and vegetables, corn, soybeans
Natria	Various	-	Consumer
Cease	<i>Bacillus subtilis</i>	0.2	Various crops
Sonata	<i>Bacillus pumilus</i>	1.0	Fruits and vegetables, berries, grapes, hops
Ballad Plus	<i>Bacillus pumilis</i>		Cereal grains, grass for seed production, vegetables, oil seed crops, sugar beets, sweet corn
Natria Insecticide, herbicide, slug and snail	Oils and fatty acids-a	3.6	Consumer OTC market
Natria consumer brands	Pyrethrin + sulfur		Consumer OTC market
Kicker, Drione, Pyrenone	Pyrethrin	2.5	Pest control, Mosquito control
Total		150.60	

a- Summary of five oil and fatty acid actives, for which individual estimates are available.

U.S. BUSINESS REVIEW

U.S. organizational structure

Bayer CropScience contains three major business groups:

- Crop Protection (food crop markets), including herbicides, insecticides, fungicides, plant growth regulators, seed treatment, and biopesticides
- Seeds, including agricultural crop seeds and genetics, vegetable seeds and genetics
- Environmental Science (professional markets), including professional products for the turf and ornamental, consumer, pest control, and vegetation management markets

FIELD SALES ORGANIZATION

Bayer's sales representatives marketing the traditional crop protection chemicals for the row crops and specialty crop markets are also marketing Bayer's line of biopesticide products. Many of AgraQuest's sales representatives have moved over to Bayer.

MANUFACTURING

Through the AgraQuest acquisition, the company owns a biopesticide manufacturing facility located in Tlaxcala, Mexico.

Bayer has also invested millions of dollars to incorporate the ability to manufacture biopesticide products within its manufacturing facilities throughout the globe.

SUMMARY OF U.S. MARKET POSITION

The 2016 year was a challenging market for many manufacturers within the crop protection industry as crop prices declined, and many growers saw tighter budgets than the year before. Despite this scenario throughout the country, Bayer was able to have a very good year compared to many of its competitors.

The company's blockbuster biopesticide product, Poncho/Votivo, continues to perform. The product will likely continue to capture additional market share within the seed treatment segment in 2015.

Expect Bayer to bring additional biopesticide products to market over the next couple years and further increase its presence within this segment of the crop protection industry.

STRATEGIC OUTLOOK TO 2021

The acquisition of Monsanto will have a transformative effect on the company and position Bayer to be a leader in chemicals, seed treatment, and biopesticides.

Bayer has stated that the company continues to focus on biological crop protection since its purchase of AgraQuest in 2012. The company believes the biopesticide segment is the fastest-growing segment in the global crop protection market.

Jon Margolis, Bayer's head of research and development for biologics, recently stated, "Biologics complement our overall portfolio of seeds, traits, chemicals, and services." Jon predicts biologics will play a significant role in changing the future of farming.

While today 55% of biological crop protection products are for use within fruits and vegetables, the demand for field crops is increasing. Bayer will likely add more biopesticide products targeting the major field crops within the next five years as biopesticides become a vital tool as part of sustainable agriculture.

Sustainable business practices will be very important within the next five years as more laws and regulations are put in place. At the same time, people are becoming more conscious of their nutrition and demanding high standards of food at the market.

Major research-based companies, such as Bayer, have a keen focus on where the opportunities in the market will be within the next 10 to 15 years, and its goal is to capture a sizeable share of the biopesticide market.

BIOSAFE SYSTEMS, LLC

SALES REVIEW

Table 86: BioSafe Systems' Sales Summary in the United States, 2014 to 2016

	\$ Million		
	2014	2016	Change, %
GLOBAL SALES SUMMARY			
Corporate global	20.0	20.0	-
Corporate U.S.	18.1	19.0	5.0
Global crop protection	20.0	20.0	-
U.S. BIOPESTICIDE SALES-a	18.1	8.0	(56.0)
a- Biopesticide sales include crop and professional markets and are stated at end user level.			

U.S. BUSINESS HIGHLIGHTS

U.S. biopesticide sales for BioSafe Systems (BioSafe) decrease 56% during 2016 to \$8.0 million. Part of this decrease may be due to selling private-label products through distributors.

Established in 1998, BioSafe is a family-owned manufacturer of biodegradable disease-control products. The company's mission is to provide disease control solutions, utilizing reduced-risk chemistries that do not negatively impact the health and safety of people and the environment. The company's main office is located in East Hartford, CT.

The company divides its business into several market segments:

- Agriculture
- Horticulture
- Post Harvest/Food Safety
- Aquatics
- Home & Garden
- Turf
- Commercial/Industrial Sanitation

New product additions/registrations from 2013 to 2016 include:

- OxiPhos bactericide/fungicide, labeled for use on citrus canker and Phytophthora.
- CalOx intended to raise soil pH and help plants take up nutrients more quickly.
- HOLDit brand of adjuvant used to control drift and deposition improvement in spraying operations.
- TerraGrow, a soil biofungicide treatment.

BioSafe Systems introduces a new post-harvest tool, FreshLock, which extends shelf life and reduces spoilage of post-harvest crops.

OWNERSHIP STRUCTURE

BioSafe Systems is a private business fully owned by the Larose family.

LICENSE/RESEARCH/MARKETING AGREEMENTS

In 2014, the company announces a new working partnership with Envera, a West Chester, Pennsylvania-based biotechnology company. BioSafe Systems will soon be introducing a range of biological-based products for a variety of applications that will include soil probiotics, pond and water treatments, enhanced biological-based cleaning and sanitation products, as well as the future development of bio-based insecticides through this partnership.

MARKETING AND SALES

Around 50% of BioSafe's sales are labeled as branded products, while the other 50% of sales are private label.

BioSafe sells their products through its fifteen sales representatives. Eleven sales representatives target the crop markets. They reach consumer through garden centers and the Internet (Amazon is a primary outlet).

U.S. CROP PROTECTION BUSINESS

Business summary 2016

BioSafe's product portfolio focuses primarily on the specialty fruit and vegetable markets, nursery/greenhouse, and potatoes. Some of their sales are through private-label products that are attributed to distributors in this study.

StorOx is for use as a spray treatment to eliminate various fungal diseases for newly harvested potatoes before storage.

Oxidate brand of hydrogen dioxide fungicide labeled for use as a seed treatment.

U.S. SALES

Table 87: BioSafe Systems' Sales in the United States, End-user Level, 2016

Line item	\$ Million
Total crop market sales	2.0
Total professional (non-crop) sales	6.0
Total consumer sales	-
Total	8.0

Table 88: BioSafe Systems' Product Group Sales Summary in the United States by Crop Market, End-user Level, 2014 to 2016

Product group	\$ Million			% Change	% Of total
	2014	2016	Change		
Fungicides	14.2	6.0	8.2	(58)	78.5
Insecticide	3.9	2.0	1.9	(49)	21.5
Total	18.1	8.0	10.1	(56)	100.0

PRODUCT LINE ANALYSIS

Based on distributor interviews, product sales are estimated for four active ingredients or combinations thereof. These sales represent six brands and are believed to be the best-selling BioSafe biopesticide products.

Table 89: BioSafe Systems' Biopesticide Sales in the United States by Active, End User Level, 2016,

Brand(s)	Active ingredient	\$ Million	Crop(s)
Oxidate	Hydrogen dioxide	3.7	Potato, vegetables
Green Clean, Terra Clean, Zeritol	Hydrogen dioxide/ peroxyacetic acid	4.3	Greenhouse, nursery, vegetables, fruit
Sanidate	Hydrogen dioxide/ peroxyacetic acid	-	Greenhouse, vegetables, fruit
Biosafe	Hydrogen dioxide/ peroxyacetic acid		Consumer
Axxe	Ammonium nonanoate	-	Greenhouse, vegetables, fruit
Total		8.0	

FIELD SALES ORGANIZATION

BioSafe has thirty sales representatives with 11 representatives targeting the crop markets and 19 focusing on the remaining segments, which include the professional ag, food safety, and commercial/industrial sanitation.

DISTRIBUTION

The majority of BioSafe's products sell through traditional national distributors. However, the company also sells to regional distributors, garden centers, and through the Internet.

MANUFACTURING

The company manufactures its products at three manufacturing locations:

- Bridgeview, IL, (main plant outside of Chicago)
- Sparta, NV, (all products west of Mississippi)
- Elizabethtown, NC

STRATEGIC OUTLOOK TO 2021

BioSafe Systems began in 1998 by the Larose family in East Hartford, CT.

The company continues to operate successfully within the highly competitive arena of the agricultural crop protection market.

It is unlikely the Larose family is interested in selling their business at this time; however, their company may be of interest to a company looking to enter the biopesticide segment or one already participating in it and wanting to grow further.

As the biopesticides market continues to grow within the United States and abroad, BioSafe Systems is well-positioned to be a key player within this market. Look for BioSafe to develop additional products targeting the major row crops of corn, cotton, and wheat.

BIOWORKS INC.

SALES REVIEW

Table 90: BioWorks Sales Summary in the United States, 2014 to 2016

	\$ Million		
	2014	2016	Change, %
GLOBAL SALES SUMMARY			
Corporate global	8.5	10.5	23.5
Corporate U.S.	6.5	9.6	47.7
Global crop protection	8.5	10.5	23.5
U.S. BIOPESTICIDE SALES-a	7.0	9.6	37.0
a- Biopesticide sales include crop and professional markets and are stated at end user level.			

U.S. BUSINESS HIGHLIGHTS

U.S. crop protection sales for BioWorks increase 37% during 2016 to \$9.6 million.

BioWorks is a leader in providing environmentally responsible, safe, and effective solutions for the growing needs of the horticulture, turfgrass, and specialty agriculture industries.

The company headquarters is in Victor, NY, just outside of Rochester.

The company states that all of its products are EPA Registered (unless exempt), and most are OMRI Listed for organic growing.

New product additions/registrations during the 2016 year include:

- Botaniguard Maxx
- Mycotol ESO
- Verdanta N-Vita fertilizer.

OWNERSHIP STRUCTURE

The company's founder is Bill Foster, President of BioWorks.

LICENSE/RESEARCH/MARKETING AGREEMENTS

In 2012, BioWorks and AEF Global sign a biopesticide distribution agreement for North America. The agreement allows AEF Global to distribute in Canada on a non-exclusive basis of several of its products, including RootShield WP, RootShield HC, and MilStop and exclusively SuffOil-X. The agreement also allows AEF Global to market these active ingredients under private label. BioWorks will distribute their biopesticides in the United States and Mexico under the private label brands AEF's Bioprotec CAF, Influence WP, and a non-selective herbicide. BioWorks will also distribute AEF's Cyclone, Tivano, Buran, Influence LC, and Kona, a selective herbicide.

BioWorks enters into a strategic alliance with DCM Corporation of Belgium, a leading producer of natural and organic-based fertilizers in Western Europe. Through this partnership, BioWorks will use DCM's fertilizer and brand it under the trade name Verdanta, including organic and organo-mineral fertilizers for professional horticulture and specialty agriculture growers.

U.S. CROP PROTECTION BUSINESS

Business summary 2016

BioWorks has built its portfolio around the professional non-crop markets with product lines extending into agricultural markets.

BioWorks' product portfolio focuses primarily on the specialty potato greenhouse, fruit and vegetable and turf markets, with some products extending into the corn and soybean crops.

BioWorks has an extensive line of products targeting the professional non-crop markets within the horticulture, turf and ornamental, and home and garden markets. The company initially sold products targeting these markets. The line includes fertilizers, fungicides and insecticides. They sell consumer products direct from their website and Amazon.

U.S. SALES

Table 91: BioWorks' Biopesticide Sales in the United States, End User Level, 2016

Line item	\$ Million
Total crop market sales	9.6
Total consumer sales	-
Total Professional (non-crop) sales	-
Total	9.6

Table 92: BioWorks' Product Group Sales Summary in the United States by Crop Market, End User Level, 2014 and 2016

Product group	\$ Million			% Change	% Of total
	2014	2016	Change		
Insecticides	2.6	1.1	(1.5)	(58)	11.0
Fungicides	4.4	8.5	4.9	(43)	89.0
Total	7.0	9.6	2.6	(60)	100.0

PRODUCT LINE ANALYSIS

Table 93: BioWorks' Product Line, Crop and Non-crop Markets in the United States, End User Level, 2016

Major brand	Active ingredient	\$ Million	Target markets
INSECTICIDES			
BotaniGard ES	Beauvaria bassiani	0.3	Potato, vegetables, fruit
Mycitrol	Beauvaria bassiani	0.2	Potato, vegetables, fruit
Mot-X	Azadirachtin	0.4	Fruit and vegetable
FUNGICIDES			
Cease	Bacillus subtilis	0.3	Potato, vegetables, fruit
RootShield, Plant shield, T-22	Trichormia harzianum	5.1	Potato, nursery greenhouse, fruit, turf
Milstop	Potassium bicarbonate	3.0	Potato, vegetables, fruit
TOTAL		9.6	

Marketing and sales programs

BioWorks' marketing and sales programs develop around the benefits of using its organic products as a safe and effective alternative to traditional chemical pesticides.

The company also markets its products designed for resistance management programs.

FIELD SALES ORGANIZATION

BioWorks organizes their field sales representatives within five regions in the United States:

- Great Lakes: Indiana, Michigan, Ohio, Illinois, Minnesota, Wisconsin
- Northeast: Connecticut, Delaware, Maryland, Massachusetts, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, West Virginia, Virginia, Vermont
- West: Alaska, California, Hawaii, Idaho, Nevada, Oregon, Washington, Montana
- Central: Arizona, Arkansas, Colorado, Iowa, Louisiana, Missouri, Mississippi, Kentucky, New Mexico, Oklahoma, Texas, Utah, Kansas, North Dakota, South Dakota, Wyoming, Nebraska
- Southeast: Alabama, Florida, Georgia, North Carolina, South Carolina, Tennessee

DISTRIBUTION

The company has a dedicated distributor relations manager. It distributes through a number of professional specialty distributors including:

- CPS
- All pro Horticulture
- Pro turf services
- Valleygreen

For the consumer market, they sell through their own website, gardeners supply and select garden centers.

MANUFACTURING

BioWorks product manufacturing is near its home office located within Victor, NY.

SUMMARY OF U.S. MARKET POSITION

BioWorks has more than 20 years experience within the biopesticide segment of the non-crop and crop protection markets.

BioWorks has developed a solid foundation of sales within the horticulture and specialty fruit and vegetable segments of the industry. The company has recently grown within this segment through the turfgrass and home and garden markets. The company has also targeted some of its products to include the major row crops.

BONIDE PRODUCTS

OVERVIEW

Bonide Products is located in Oriskany, NY, and was established in 1926 by James H. Wurz. The company is privately owned by the third generation of the Wurz family. The consumer product line, marketed under the Bonide label, consists of around 235 products, most of which are available in several packaging options. Bonide Products also manufactures a wide range of products under private labels for other suppliers.

SALES AND PROFITS

Bonide Products continues to experience growth as a result of an ongoing initiative to expand beyond its traditional regional focus of the U.S. Northeast. Since 2008, there has been a slowdown in sales due to the economic slowdown and stronger competition. Biopesticide sales in 2016 are estimated at \$9.6 million. Sales of all consumer pesticides are estimated at \$25 million, not very different than Kline's estimate of \$23.5 million in 2011. Consumer products account for approximately 70% of Bonide's sales, while the remaining 30% is made up of contract manufacturing for professional pest control companies. Consumer product sales are divided among insecticides, herbicides, fungicides, rodenticides, and other products such as repellents and fertilizers. Insecticides remain the largest product category with 50% of the consumer business.

CONSUMER PESTICIDE

Bonide has a wide range of insecticides, herbicides, fungicides, rodenticides, repellants, and fertilizers distributed in the categories: Household Pest Control, Garden Naturals, Insect Control, Weed Control, Disease Control, Repellants and Specialty, Insect and Disease Combination Products.

Biopesticide sales are estimated at \$9.6 million, with pyrethrin products leading the way, followed by Azadirachtin and Neem Oil.

Table 94: Bonide's Sales of Pesticides and Related Products to Consumer Markets in the United States by Category, 2011

Product category	\$ Thousand	% Of total
INSECTICIDES		
Outdoor	10,625	45.0
Household	1,125	5.0
Total	11,750	50.0
HERBICIDES		
Lawn	2,500	10.0
Specialty	2,500	10.0
Total	5,000	20.0
FUNGICIDES	2,500	10.0
RODENTICIDES	2,250	10.0
REPELLENTS	1,125	5.0
FERTILIZERS	1,125	5.0
TOTAL	23,500	100.0

Table 95: Bonide Biopesticide Sales in the United States, 2016

Active ingredient	Brand(s)	\$ Million
Pyrethrin, Pyrethrin combinations	Japanese Beetle Killer, Garden Dust, Garden Spray, Tomato & Vegetable 3 in 1	3.0
Azadiractin	Bio-Neem, Citrus, Fruit & Nut Orchard Spray,	1.8
Neem Oil	Rose RX, Bon-Neem II	1.3
Citric acid + clove oil	Burn Out Weed & Grass Killer	0.8
Cotton gluten	Maize Weed Preventer	0.7
Bacillus thuringiensis	Thuricide Bacillus Thuringiensis Concentrate	0.5
Cotton seed oil, clove oil, garlic extract	Mite X	0.5
Diatomaceous earth	Diatomaceous earth	0.5
Horticultural oil	Horticultural Oil	0.4
Capsaicin	Hot Pepper Wax Insect Repel	0.3
Total		9.6

MARKETING POLICIES

Bonide focuses its marketing efforts on independent lawn and garden retailers, but also sells to regional chains and some national chains on a regional basis. A vice president of sales and marketing oversees all sales and marketing activities, supported by four regional sales managers located in Tulsa, OK; Richmond, VA; Omaha, NE; and Tacoma, WA. Approximately 30 manufacturers' representatives augment the company's sales force.

FACILITIES

Bonide operates out of an expanded 275,000-sq-ft manufacturing and distribution facility, completed in 2003. The facility also houses the corporate offices. The production area is state-of-the-art and includes liquid, dry, and granular production lines. As of December 2016, Bonide employed 210 people.

BRANDT CONSOLIDATED, LLC

SALES REVIEW

Brandt Consolidated, Inc. has sales of \$9.9 million in 2016, an increase of 110% from sales of \$4.7 million in 2014. All of Brandt Consolidated's pesticide sales are for biopesticides.

U.S. BUSINESS HIGHLIGHTS

Brandt was founded in 1953 by Glen Brandt, and his sister, Evelyn Brandt Thomas, to help Illinois farmers adopt new and profitable technologies. Over the past decade, the company has experienced aggressive growth under the leadership of President and CEO Rick Brandt.

Brandt is a leading agriculture-oriented company consisting of three divisions:

- Specialty Formulations
- Retail Agronomy
- Dealer Support

For the fifth time, Brandt is named to the 2014 *Inc.* magazine's Inc. 5000, a ranking of the nation's fastest-growing private companies. The company ranked number 4,622 among the 5,000 companies profiled.

The company experienced significant growth in its business through acquisitions and organic market expansion during 2015-2016.

In 2016, BRANDT acquired the assets of Tratamientos Guadalquivir S.A. (TRAGUSA) under its subsidiary BRANDT Europe, S.L. TRAGUSA, based in Carmona, Spain, and manufactures, distributes, and sells specialty fertilizers, adjuvants, and a full line of crop protection products.

In 2016, BRANDT is expanding its pest management product line and rolling out 10 new pest management products. BRANDT's pest management portfolio focuses on products that are sustainable and environmentally responsible. The rollout is a natural progression for the company. BRANDT has a robust sustainable product line and has been a leading supplier of soft chemistries for the agriculture market for over 30 years.

The company divides its business into several market segments:

- Agriculture
- Horticulture
- Post Harvest/Food Safety
- Aquatics
- Home & Garden
- Turf
- Commercial/Industrial Sanitation

New product additions/registrations in 2016 include:

- OxiPhos bactericide/fungicide, labeled for use on citrus canker and Phytophthora.
- CalOx intended to raise soil pH and help plants take up nutrients more quickly.
- HOLDit brand of adjuvant used to control drift and deposition improvement in spraying operations.

OWNERSHIP STRUCTURE

Brandt is fully owned by the Brandt family.

ACQUISITIONS

During the 2013-2014 year, Brandt acquired the following companies:

- Monterey AgServices
- Hardy Fertilizer
- Niantic Crop Service
- Grigg Brothers
- Lemon Ag Services

The acquisition of Monterey gave Brandt access to the consumer market and added several biopesticides to their portfolio. In general, these biopesticides are produced by others but sold through the Monterey distribution system.

In 2016, BRANDT acquired the assets of Tratamientos Guadalquivir S.A. (TRAGUSA) under its subsidiary BRANDT Europe, S.L. TRAGUSA, based in Carmona, Spain, manufactures, distributes and sells specialty fertilizers, adjuvants, and a full line of crop protection products.

JOINT VENTURES

Brandt forms joint venture with Innovation Hammer, a company dedicated to improving plant health and yields through field-tested breakthroughs in technologies and science. The JV gives the company access to unique glycoregulator technologies.

The company acquires a stake in Spanish tree injection company Fertinyect, S.A. headquartered in Cordoba, Spain. Fertinyect is known for its patented low-pressure tree injection (LPTI) systems for use in global agriculture and landscape markets to promote tree health. The transaction gives Brandt exclusive distribution and manufacturing rights for the use and sale of the injection device in the agricultural industry in the United States.

R&D

Brandt expects to build upon its existing R&D efforts within the next five to ten years through its goal of introducing new products.

U.S. CROP PROTECTION BUSINESS

Biopesticide business summary 2016

Brandt sells its organic products through its Specialty Formulations division, which received a significant boost when Brandt purchased Monterey AgResources in March 2010. The renamed Brandt Monterey is a wholesale supplier of specialized nutrients, adjuvants, and biopesticides to the agricultural, horticultural, lawn and garden, and feed industries.

Brandt has an extensive line of over 50 organic products approved by the following:

- Organic Materials Review Institute (OMRI)
- National Organic Program (NOP)
- Washington State Department of Agriculture (WSDA)

The company segments its sustainable portfolio of products within six categories:

- Adjuvants & Irrigation Aids
- Disease Management
- Insect Management
- Nematode Management
- Micronutrients & Yield Enhancing Formulations
- Crop Nutrients

Product focus

This report focuses on Brandt's organic product portfolio within following crop and non-crop markets:

- Major row crops
- Specialty fruit and vegetables
- Turf and ornamentals
- Consumer

U.S. SALES

Table 96: Brandt's Biopesticide Sales in the United States, End User Level, 2016

Line item	\$ Million
Total crop market sales	5.5
Total consumer Sales	3.3
Total Professional (non-crop) sales	1.1
Total	9.9

Table 97: Brandt's Biopesticide Product Group Sales Summary in the United States by Crop Market, End User Level, 2014 and 2016

Product group	\$ Million			% Change	% Of total
	2014	2016	Change		
Insecticides	0.6	3.2	2.6	433	32
Fungicides	3.5	5.5	2.0	57	55
All other	0.9	1.2	0.3	33	12
Total	5.0	9.9	4.9	98	100

PRODUCT LINE ANALYSIS

Adjuvants and irrigation aids

Brandt markets six products within its Adjuvants & Irrigation Aids organic product line.

Disease management

Brandt's Disease Management product line contain the following active ingredients to control a wide range of blight, algae, leaf spot, powdery mildew, and more:

- Sulfate
- Sulfur
- Potassium bicarbonate
- Copper
- Oils
- Fungus *Ulocladium oudemansii*

Insect management

Brandt's Insect Management segment contains nine products, with active ingredients which include pyrethrins and oils.

Nematode management

The company offers two products under this segment:

- Nema-Q, containing *Quillaja saponaria* to target ectoparasitic and endoparasitic nematodes
- Sesamin, based on sesame oil

Micronutrients and yield enhancing formulations

Eight products containing micronutrients, which prevent and correct mineral deficiencies in field, row, vegetable, fruit, tree, vine, ornamental and turf crops.

Brandt provides yield enhancing products which contain complex minerals to maximize production, enhance yield and correct deficiencies.

A portfolio of 14 crop nutrient products which are offered in dry or liquid form. Several products are recommended for correction of manganese deficiency.

Biopesticide products

Table 98: Brandt's Biological Product Line in the United States, End User Level, 2016

Major brand	Active ingredient	\$ Million	Target market(s)
INSECTICIDES			
Ecotec (2)	Ecotec	1.10	Vegetables, fruit
Sluggo Plus	Iron phosphate/spinosad	0.75	Turf and ornamentals, fruit, vegetables
Veratran D	Sabadilla Alkaloids	0.17	Fruit
NeemAQ	Saponins	0.15	Fruit
FUNGICIDES			
Kaligreen Bi-Carb	Potassium bicarbonate	2.70	Fruits, vegetables, ornamentals
BioSide HS	Peroxyacetic Acid/Hydrogen Peroxide	0.10	Nursery greenhouse
Bloom Time Bio	Pantoea agglomerans strain E325	0.50	Fruit
Tres Oil	Vegetable oil	1.70	Various specialty fruit, vegetables, and nut crops
Brandt Other		2.73	Consumer
Total		9.90	

U.S. BUSINESS REVIEW**U.S. organizational structure**

Although it operates under the umbrella of a single company, Brandt consists of three distinct divisions, with each contributing approximately one-third to overall revenue:

- Retail Agronomy
- Dealer Support
- Specialty Formulations

Brandt's Retail Agronomy division services more than 1 million acres of Central Illinois farmland from 20 outlets.

The Dealer Support division supplies fertilizer and nitrogen to agricultural and industrial customers around the country.

The third division, Specialty Formulations, is Brandt's line of organic products. Its Specialty Formulations division is currently in an aggressive expansion mode in terms of products, geographies and capabilities. In November 2014, Brandt acquired a neighboring 96,000-square-foot facility to produce organic agricultural nutrients in Fresno, CA, in an effort to separate organic from conventional production, and lessen the potential for cross-contamination.

Product management strategies

Brandt has a two-pronged approach to its product portfolio:

- In house formulations of its own proprietary products and blends
- Acquiring private label products from crop protection manufacturers

A sample list of manufacturers selling crop protection chemicals to Brandt include:

- Aceto Chemical
- Arysta LifeScience
- Drexel Chemical
- Otsuka Chemical Company
- Monterey Ag Resources
- Nufarm

FIELD SALES ORGANIZATION

Brandt has an established sales and marketing structure through distributors for selling its products in the ag space. For consumers, it sells through Ace hardware and independent land and garden centers.

The company sees all the recent consolidation at the ag retail level as a benefit, because talented people looking for jobs are working for Brandt.

SUMMARY OF U.S. MARKET POSITION

Brandt's Specialty Formulations division (containing its biopesticide portfolio) is in an aggressive expansion mode in terms of products, geographies, and capabilities. In 2016, the company increased sales within this division by 98%.

To accommodate this new growth within Specialty Formulations, the company recently acquired a 96,000-square-foot facility to produce its organic product line in Fresno, CA.

As the biopesticide market continues to grow, the company plans to be developing new organic products for the future to remain competitive. Expect Brandt to remain a key player within the U.S. biopesticide market over the next five years.

STRATEGIC OUTLOOK TO 2021

During the past 10 years, the company has diversified its business, adding divisions and new market areas, including its Specialty Formulations division which houses its biological product line.

The demand for organic products has been rising in recent years and the company is expected to remain a key player within the U.S. and international biopesticide market.

The company could likely be an acquisition candidate for a mid-to-large agricultural retailer looking to grow within the Illinois market, while bringing in a solid portfolio of private-label products, along with a well-established biological business with international presence.

CERTIS USA

SALES REVIEW

Certis USA has biopesticide sales of \$20.1 million in 2016, an increase of 3.6% from \$19.4 million in 2013.

U.S. BUSINESS HIGHLIGHTS

Certis USA (Certis) develops biological pesticides and has become one of the world's leading manufacturers and distributors of biopesticides. Headquarters are located in Columbia, MD. The company currently employs 100 people within the United States.

The company specializes in:

- Biological product development, from screening to formulation to field development
- Manufacturing including fermentation and formulation
- Global registrations for biological products
- Global sales channels

Certis markets its biological products within the following markets:

- Agriculture
- Turf
- Nursery and greenhouse
- Home and garden

New product introductions for 2015 include:

- Double Nickel 55 fungicide/bacteriacide

OWNERSHIP STRUCTURE

In 2001, Mitsui & Co, a leading Japanese trading company, acquired Thermo Trilogy and renamed it Certis USA LLC. The company has grown through a series of acquisitions. Within Mitsui's AgriScience Division, Certis USA is positioned as the global competence center for biological control technologies.

ACQUISITIONS (PAST-PRESENT)

The company began with the formation of Thermo Trilogy in 1996, followed by the acquisition of neem and microbiol technologies from W.R. Grace.

Certis then acquired baculovirus and neem products from Biosys in 1997 and Bt bioinsecticide products from Novartis in 1997.

In 2002, Certis purchased certain assets of the U.S. biopesticide company, Ecogen. Assets included Ecogen's *Bacillus thuringiensis* (Bt) biopesticide and insecticidal nematode businesses. In 2017, Certis USA acquires 100% of the shares of Butte, Montana-based LAM International. LAM International is a developer and manufacturer of several leading bioinsecticide products, including Botanigard and Mycotrol, and has a pipeline of newly registered products and others currently under registration and development.

MARKETING & SALES

Certis states its sales and technical service teams work closely with researchers, farm advisors, consultants and growers to fit its products to specific market needs. The company has 11 sales representatives, as well as three technical service representatives and a consumer sales manager. Certis has been very effective at sales through consumer marketers and has products placed with all the consumer companies including Bonide, Scotts, Woodstream and VPG. Sales of these products will be reported under the marketer's sales.

The company has grown by identifying and acquiring products that complement its product line.

U.S. BIOPESTICIDE SALES

Table 99: Certis' Biopesticide Sales in the United States, End-user Level, 2016

Line item	\$ Million
Total crop market sales	28.3
Total professional (non-crop) sales	1.1
Total	29.4

Table 100: Certis' Biopesticides Sales Summary in the United States by Crop Market, End-user Level, 2014 and 2016

	\$ Thousand			
Product group	2014	2016	% Change	% Of total
Insecticides	16,700	12,800	23.3	43.5
Fungicides	3,300	16,300	393.0	55.4
Molluscicide	100	300	300.0	1.0
Total	20,100	29,400	46.3	100.0

PRODUCT LINE ANALYSIS

With over 30 registered products, Certis has one of the most extensive lines of products within the biopesticide segment of the crop protection industry. It added Lifeguard to the portfolio in 2015 for potatoes. The acquisition of Lam will expand its portfolio.

Field crop markets

The majority of Certis' products target the specialty fruit, vegetable, and greenhouse crops.

Table 101: Certis' Biopesticide Sales in the United States by Product, End-user Level, 2016

Brand(s)	Active	\$ Thousand	Target market(s)
INSECTICIDE/NEMATOCIDE			
Condor, Lepinox, Crymax, Thuricide, Javelin	<i>Bacillus thuringiensis</i> Kurstaki	0.8	Potato, greenhouse, vegetables, fruit
Azatin, Neemazad, Neemix, Trilogy	Azadirachtin	5.5	Potato, greenhouse, vegetables, fruit, consumer
Agree, Design, Florbac, Jackpot, Ketch	<i>Bacillus thuringiensis aizawai</i> GC91	1.8	Potato, greenhouse, vegetables, fruit, consumer
Madex HP, carpovirusine, Cyd-X, Virosoft	<i>Cydia pomonella granulovirus</i> V22	1.5	Fruit
MeloCon WG, BioAct, Bio-Nematon	<i>Paecilomyces lilacinus</i> PL251		Fruit
Trilogy, Green Light	Neem Oil	2.0	Specialty, potatoes, greenhouse, vegetables, fruit, OTC
PreFeRal, PFR-97, Priority	<i>Paecilomyces fumosoroseus</i>	1.2	Potato, greenhouse, vegetables
Spod-X	<i>Spodoptera exigua</i> NPV	0.1	Nursery greenhouse
Gemstar	<i>Heliothis zea</i> NPV	-	Field crops
PFR	<i>Isaria fumosorosea apopka 97</i>	0.3	Potato
Des-X	Potassium salts of fatty acids	0.5	Vegetables, fruit
Sluggo	Iron phosphate		Nursery, greenhouse, vegetables, fruit, turf
FUNGICIDE			
Cueva	Copper octanate	3.0	Specialty, potatoes, greenhouse, vegetables, fruit
BioSide, Rendition	Hydrogen peroxide/ peroxyacetic	0.3	Potato, vegetables
Tavano	Polyo1in D Zinc	0.5	Vegetables, fruit, turf, nursery, greenhouse
Sil-Matrix	Potassium silicate	0.5	Fruits, vegetables
Double Nickel 55, Double Nickel LC	<i>Bacillus subtilis amyloliquefaciens</i> D747	3.6	Specialty, potatoes, greenhouse, nursery
SoilGard	<i>Gliocladium virens</i> GL-21	1.0	Vegetables, fruit
Kocide	Copper	5.0	Vegerables Fruit
Lifegard		0.2	Potato
OSO	Poly-D Zinc	0.7	Fruit, turf
Molluscicide			
Sulgo	Ironphosphate	0.3	Nursery greenhouse
TOTAL		29.4	

U.S. BUSINESS REVIEW

U.S. organizational structure

Certis has an established sales and marketing structure for selling its products.

The company has one National Ag Business Manager with eight regional managers that cover the entire United States, including three located in Florida and two based in California. The company has hired experienced sales representatives within the agricultural industry, specifically individuals with prior biopesticide knowledge.

Product management strategies

Certis develops its own products, from screening to formulation to field development. The company specializes in:

- Manufacturing processing includes fermentation and formulation
- U.S. and global registrations for biological use
- U.S. and global sales channels

Certis has three product managers:

- Two managers for its Ag product portfolio
- One for Home and Garden

The company believes to be an innovator in the following technology categories:

- Neem extracts (azadirachtin and clarified hydrophobic extract of neem oil).
- *Bacillus thuringiensis* Bioinsecticides
- Baculovirus technologies
- Pathogenic and pesticidal fungi technologies

Many of Certis products are approved for use or are listed for use in organic production.

Table 102: Certis USA Products Approved for Organic Production (NOP compliant) in the United States

Agree WG	MeloCon
CoStar	Neemazad
CYD-X	Neemix
CYD-X HP	Nimbuz
Deliver	Seduce
DES-X	Sil-MATRIX
Gemstar LC	SoilGard
Javelin	Trilogy

Marketing and sales programs

Certis maintains a basic strategy of marketing to the major distributors, as well as the large ag retailer and smaller farm retail outlets.

MANUFACTURING

Certis has fermentation facilities in Wasco, CA, and a neem extraction plant in India with a joint-venture partner.

STRATEGIC OUTLOOK TO 2021

Certis is one of the leading biopesticide manufacturers within the U.S. crop protection industry. With Mitsui & Co. as its parent company, Certis has the support of a large Japanese trading company.

The company is positioned as the global competence center for biological control technologies.

GOWAN COMPANY

SALES REVIEW

Table 103: Gowan's Sales Summary in the United States, 2014 to 2016

	\$ Million		
	2014	2016	Change, %
GLOBAL SALES SUMMARY			
Corporate global	470	530	12.8
Corporate U.S.	360	418	16.1
Global crop protection	290	371	27.9
U.S. CROP PROTECTION CHEMICALS			
Crop markets	113	170	50.4
Professional markets	15	19	26.7
Total	128	189	47.6
U.S. BIOPESTICIDE SALES-a	3.0	3.3	10.0

a- Biopesticide sales include crop and professional markets and are stated at end-user level.

U.S. BUSINESS HIGHLIGHTS

U.S. biopesticide sales increase 10% during 2016 to \$3.3 million. The Gowan Company (Gowan) is a generic manufacturer of crop protection products for the crop and professional markets based in Yuma, AZ. Gowan labels its line of biopesticides as its Biorational business, which operates out of its Gowan USA headquarters in Overland Park, KS.

In 2016, Gowan lists 64 products, with 58 unique brands and three generic names. The company is building its fungicide portfolio to include products targeting row crops.

Gowan signs an exclusive distribution agreement with Isagro S.p.A. with its Domark 230 ME fungicide for use on corn and soybeans. Domark is based on the active ingredient, tetraconazole.

Gowan's biopesticide product line consists of three active ingredients:

- Azadirachtin
- Pelgaric acid
- *Trichoderma gamsii asperellum*

OWNERSHIP STRUCTURE

The Gowan Company (Gowan) was founded in 1975 by owners, Jon Jessen and family. Gowan is a privately-owned company with reported corporate global sales of \$455 million.

MARKETING AND SALES

Gowan fits a similar pattern with other companies in developing an off-patent brand strategy, but it works to retain a uniqueness in its approach to marketing. Its marketing strategy is built around product registration activities. The company recently moved into field crop markets, including corn, cereals, sorghum, and rice.

ACQUISITIONS/AGREEMENTS: INTERNATIONAL BIOPESTICIDES

Gowan signs agreement with Azul Natural SA de CV of Durango, Mexico, where the company assigns Gowan as its exclusive worldwide partner for development, registration, marketing, and distribution. Azul Natural develops microbiological and biochemical based products. Azul Natural's existing products in addition to its well-populated pipeline will add to Gowan's portfolio of biopesticide products.

Gowan reaches an agreement with EcoFlora to create a joint venture called EcoFlora AGRO. Through this joint venture, Gowan and its global marketing companies will be the exclusive partner in developing, registering, and marketing EcoFlora's current unique plant extract-based portfolio and its robust product pipeline. EcoFlora Agro is a Colombian company which develops innovative solutions from plant extracts for the sustainable and safe production of crops. Gowan Company announced in 2015 that it has entered into a definitive agreement to acquire the entire global dinitroaniline (DNA) herbicide portfolio from Dow AgroSciences LLC, a wholly-owned subsidiary of The Dow Chemical Company (NYSE: DOW). The acquisition includes global product registrations, trademarks, including Treflan, Edge, Team, Bonalan, and Sonalan; and intellectual property and labels for herbicides based on the molecules trifluralin, benfluralin, and ethalfluralin. A formulation and packaging facility in Sturgeon County, Alberta, Canada, is also part of the transaction. In 2016, a License and Supply Agreement was finalized between Isagro and Gowan Crop Protection Limited for the long-term marketing and development of the proprietary fungicide, Kiralaxyl, in Europe, thus strengthening the strategic alliance between Isagro and Gowan. In 2016, the company announces the Federal EPA registration of Magister SC miticide. Magister SC is registered to control mites in almonds, cherries, Christmas trees, non-bearing tree fruits, and nuts; and powdery mildew in cherries. Magister was also approved in California for almonds and cherries in January 2016.

U.S. CROP PROTECTION BUSINESS

Gowan's biorational business consists of the following products:

- Aza-Direct
- M-pede
- Scythe
- Badge (Copper)
- Previsto (Copper)
- Captiva
- Prokil (Diatomaceous earth)

U.S. SALES

Table 104: Gowan Biopesticide Sales in the United States, End-user Level, 2016

Line item	\$ Million
Total crop market sales	1.7
Total professional and non-crop sales (OTC)	1.5
Total	3.3
Estimated.	

Gowan's biopesticide products have expanded since the last edition of this report in 2014, reflecting the demand for biopesticides in the fruit and vegetable markets.

PRODUCT LINE ANALYSIS

Table 105: Gowan's Biopesticide Product Sales in the United States, End-user Level, 2014 and 2016

	\$ Million			
Major brand	Active ingredient	2014	2016	Target markets
INSECTICIDES				
Aza-Direct	Azadirachtin	2.8	2.5	Greenhouse, potatoes, flowers, trees, shrubs and plants
Pro-kil	Diatomaceous earth	-	-	Fruits and vegetables
Captiva	Capsicum, Garlic oil, Soybean oil	-	-	Fruits and vegetables
M-Pede,S	Potassium salts of fatty acids	0.2	0.8	Potatoes, Fruits and Vegetables
FUNGICIDES				
Badge	Copper	-	-	Fruits and vegetables
Provisto	Copper	-	-	Fruits and vegetables
TOTAL		3.0	3.3	

U.S. BUSINESS REVIEW

Product management strategies

Gowan has experience expanding product registrations of several of its key products under its chemical portfolio. Expect the company to begin expanding its registrations for its biopesticide products into new crop markets.

SUMMARY OF U.S. MARKET POSITION

Gowan's biorational product line currently has a portfolio of three products. Sales of \$3.3 million within this segment are worthy enough to include within this report.

Gowan is a respected marketer within the crop protection industry that has found its niche within the specialty crop markets, particularly fruits, nuts, and vegetables in California and Florida.

STRATEGIC OUTLOOK TO 2021

Gowan's small and private company culture allows it to operate within the specialty crop markets often under the radar of the large, research-based manufacturers.

The company has a significant international presence for its size that will benefit its global crop protection business as the company enters into new geographical markets over the next five years.

Gowan is expected to remain among the leading 15 companies within the U.S. crop protection chemical market through 2021, with a move to add more products to its biorational portfolio. With current agreements with international companies, such as Ecoflora and Azul Natural, Gowan can form a biopesticide product line worthy of making an impact over the next five to 10 years.

GREEN LIGHT COMPANY (Scotts Miracle Grow)

OVERVIEW

Until August 2008, Green Light Company of San Antonio, TX, was a 100% employee-owned company, which was founded in 1947 as the Klauss-White Company. The original Klauss-White Company produced quality lawn and garden products for sale to homeowners, ranchers, farmers, and pest control operators. In 1959, the company name was officially changed to the Green Light Co.

The company was purchased by Valent in 2008 and operated as a subsidiary.

In April 2012, The Scotts Miracle-Gro Company purchased Green Light.

More recently, Green Light has been moving toward new organic and natural product lines, which are more environmental friendly.

In October 2003, Green Light and CedarCide Industries entered into a key agreement for Green Light to manufacture and market the retail line of chemical-free CedarCide products, which are derived from Texas Red Cedar. In addition, Green Light acquired the rights to sell Spinosad, a naturally derived pesticide from Dow AgroSciences.

SALES AND PROFITS

Green Light does not release financial information. Sales for fiscal year 2016 are estimated at \$25 million and included in the Scotts total.

BIOPESTICIDE SALES

Green Light sales of biopesticides are estimated at \$10 million, all based on Azadirachtin, but divided evenly between basic neem oil and more refined azadirachtin, and are included in the Scotts total.

Table 106: Green Light Sales of Biopesticides to Consumer Markets in the United States, End-user Level, 2016

Active	Brands	\$ Million
Azadiractin	Rose Defense, Rose Defense RTU	5.0
Neem Oil	Neem Concentrate, Neem II RTU	5.0
Total		10.0

MARRONE BIO INNOVATIONS (MBI)

SALES REVIEW

Marrone Bio Innovations (MBI) has sales of biopesticides totaling \$26.0 million in 2016, up by 100% from \$13.0 million in 2014.

U.S. BUSINESS HIGHLIGHTS

MBI was founded by Dr. Pamela Marrone (CEO) in 2006 to discover and develop effective and environmentally-responsible, biologically-based products for pest management and plant health.

The company describes itself as a leading provider of bio-based pest management and plant health products for the agriculture, turf and ornamental, and water treatment markets.

MBI is based in Davis, CA. The manufacturing plant is located in Bangor, MI.

New product additions/registrations in 2016:

- EPA registered MBI-601 biofumigant, which should be available in late 2017.
- Majestene bionematicide was launched and awarded “Best New Biopesticide” by Agrow.
- The company signed an agreement to distribute Haven anti-transparent.
- MBI signed a distribution agreement with Koch Agronomic Services and Albaugh for row crop applications.
- It launched Grandevo WDG formulation.

OWNERSHIP STRUCTURE

MBI is a public company. In August 2013, the company was listed on the NASDAQ exchange, raising net proceeds of \$56.4 million.

LICENSE/AGREEMENTS/JOINT VENTURES: UNITED STATES

MBI secures license agreement from Kao Corporation for plant health active ingredient. The company expects to use the active in the development of products involving plant and naturally-based compounds in the United States. The agreement grants MBI exclusive commercial development and marketing rights to all conventional and organic agricultural uses, in addition to all turf and ornamental, home and garden, and forestry uses.

The company signs exclusive use license for the patent properties covering various uses of a plant endophyte from Brookhaven Science Associates, LLC. MBI will use a naturally occurring endophyte in the development of products involving plant health. The agreement grants MBI exclusive commercial development and marketing rights to horticultural uses of the endophyte in the United States, Canada, Mexico, New Zealand, Australia, and member states of the European Patent Organization.

MBi signed an agreement with Koch Agronomic Services, LLC (Koch), with support from its affiliate, Koch Biological Solutions, LLC, to sell REGALIA Rx in the U.S. and REGALIA Maxx in Canada. Koch will market and sell the products for broad-acre agriculture applications. REGALIA Rx and REGALIA Maxx are manufactured by Marrone Bio Innovations, Inc. (MBI) (NASDAQ: MBII) and improve crop performance by providing defense against fungal pests. Both products also offer significant plant health benefits.

Marrone Bio Innovations, Inc. announced that the United States Environmental Protection Agency (EPA) has approved funding, under the Great Lakes Restoration Initiative (GLRI), to assess new, non-enclosed open water application techniques with Zequanox. Cameron Davis, senior advisor to the U.S. EPA administrator, stated that this application could “potentially expand invasive zebra and quagga mussel control possibilities throughout the Great Lakes Basin.”

In 2016, Marrone Bio Innovations, Inc. and Groundwork BioAg, Ltd (GBA) announced a collaboration to create and commercialize the world’s first all-biological comprehensive seed treatment. The treatment is expected to contain a mycorrhizal biostimulant from GBA as well as a bioinsecticide, a bionematicide, and a biofungicide from MBI.

Marrone Bio Innovations, Inc. (MBI), (NASDAQ: MBII), a leading provider of bio-based pest management and plant health products for the agriculture, turf and ornamental and water treatment markets, announced in July 2016 that Health Canada’s Pest Management Regulatory Agency (PMRA) has approved two Regalia products for home and garden uses in Canada.

Marrone Bio Innovations, Inc. announced in July 2016 that Health Canada’s Pest Management Regulatory Agency has approved REGALIA Rx Biofungicide for use on wheat and soybean in Canada.

Albaugh, LLC, and Marrone Bio Innovations, Inc. (NASDAQ: MBII) (MBI), announced in August 2016 that the companies have signed an exclusive agreement to develop and market one of MBI's microbial products, a proprietary microbial biopesticide with insecticidal and nematocidal properties, for seed treatment applications. The BLOST product is launched in 2017.

R&D

MBI creates products from microorganisms isolated from samples collected from unique niches and habitats, such as flowers, insects, soil, and composts.

The company has its own proprietary technology enabling it to screen in excess of 16,000 microorganisms and hundreds of plant extracts, which has produced numerous product candidates that display activity against insects, nematodes, weeds, plant diseases, and invasive species, such as zebra and quagga mussels, aquatic weeds, and algae.

MBI signs R&D agreement with DSM Food Specialties involving early stage research of several biological active ingredients. The agreement's goal is to unlock the full potential of biological active ingredients to improve the critical end points—crop production and food safety—of the food supply chain. MBI and DSM will exchange microorganisms from their libraries in order for their respective research teams to screen for biological activity in their specific areas of interest.

MARKETING AND SALES

The company's U.S. marketing and sales takes place out of its Davis, CA, headquarters. It is currently hiring sales managers for various regions within the United States and South America.

The company believes it has a “compelling value proposition” for its biopesticide products, which include:

- Higher yields and quality in programs
- No residues, good for export markets
- Manage/delay pest resistance
- Worker safety and production flexibility (short field re-entry)
- Favorable environmental footprint
- Lower develop costs
- Can be used in organic production

LICENSE/RESEARCH/JOINT VENTURES: INTERNATIONAL

MBI signs research agreement with The New Zealand Institute for Plant & Food Research Limited. The collaborative agreement covers a number of novel bio-active organisms and natural products which Plant & Food Research will provide to MBI for the expected development of biopesticides and plant health products. The MBI field of use includes conventional and organic agricultural uses, turf and ornamental, home and garden, and forestry. In 2011, The Scotts Miracle-Gro Company and Marrone Bio Innovations (MBI), announced exclusive research and development agreement designed to provide consumers new natural plant protection products. Under terms of the deal, ScottsMiracle-Gro gains access to MBI's full portfolio of innovative biopesticides for the development of new products for the lawn and garden market. The two companies collaborate on research and development efforts, and MBI manufactures and supplies any resulting products, while ScottsMiracle-Gro maintains worldwide marketing rights. Financial terms of the deal were not disclosed.

MBI signs collaboration agreement with Valagro S.p.A. in 2016 to collaborate in the discovery and development of agricultural products. Under the agreement the companies will provide each other access to certain intellectual property, active ingredients, and formulations and evaluate the performance of combinations of technologies for commercial use.

The company signs a multiyear collaborative agreement with Evogene, targeting the joint discovery of novel modes of biological action for insect control, followed by the development and commercialization of new insect control products by each of the companies. The partnership will leverage the expertise and distinct assets and capabilities of each company in its respective field, namely MBI's expertise in microbial-based solutions for pest control and plant health, and Evogene's computational gene discovery capabilities.

Marrone Bio Innovations, Inc. and Groundwork BioAg, Ltd (GBA) announce a collaboration to create and commercialize the world's first all-biological comprehensive seed treatment. The treatment is expected to contain a mycorrhizal biostimulant from GBA as well as a bioinsecticide, a bionematicide, and a biofungicide from MBI.

U.S. CROP PROTECTION BUSINESS

MBI currently has only four commercially available products available with two additional which have been approved by EPA and one submitted for EPA registration.

MBI's currently offers its Regalia Rx biofungicide for the row crop market.

MBI offers Zequanox for invasive mussel control in the Great Lakes.

MBI also distributes Bio-Tam 2.0 for Isagro in the western United States.

The company offers five products targeting the specialty fruit and vegetable markets:

- Regalia biofungicide
- Grandevo bioinsecticide
- Venerate bioinsecticide
- Majestene Nematicide
- Bio-Tam 2.0 fungicide

U.S. SALES

Marrone Bio Innovations has sales of \$18.6 million in 2016. Of the total, fungicides account for \$11.3 million and insecticides and nematicides for the remaining \$7.3 million.

Table 107: Marrone Bio Innovations' Product Group Sales Summary in the United States by Crop Market, End-user level, 2014 and 2016

	\$ Million				
Product group	2014	2016	Change	% Change	% Of total
Nematicide	-	0.2	0.2	-	1.1
Molluscicide	-	2.0	2.0	-	11.0
Insecticides	3.0	5.1	2.1	70	27.4
Fungicides	10.0	11.3	1.3	13	60.7
Total	13.0	18.6	5.6	43	100.0

PRODUCT LINE ANALYSIS

MBI separates its products under the following categories:

- Bioinsecticides
- Biofungicides
- Bionematicides
- Molluscicide
- Antitranspirant

The company plans to launch new products during 2017, including a biofumigant and has three additional products currently under EPA approval.

Regalia Rx fungicide is labeled for use in corn, soybeans, wheat, and barley.

Grandevo and Venerate, Venerate XC insecticides are labeled for use in corn, wheat, and barley.

MBI currently has its available products targeting 30+ specialty fruit and vegetable crops.

Table 108: Marrone Bio Innovations Product Line for Crop Markets in the United States, End-user Level, 2016

Major brand	Active ingredient	\$ Million	Target market(s)
INSECTICIDES			
Grandevo	<i>Chromobacterium subtsugae</i>	4.5	Potatoes
Venerate XC	Burkholderia species MBI 396	0.6	Fruit
FUNGICIDES			
Bio-Tam	<i>Trichoderma asperellum</i> , <i>Trichoderma gamsii</i>	1.0	Row crops, Greenhouse, Nursery
Regalia	<i>Reynoutria sachalinensis</i>	4.8	Potatoes, nursery, vegetables, fruit
Regalia Rx	<i>Reynoutria sachalinensis</i>	4.5	Potatoes, nursery, vegetables, fruit
NEMATOCIDES			
Majestene	<i>Burkholderia spp.</i>	0.2	Potatoes, nursery, vegetables, fruit
MOLLUSCICIDE			
Zequanox	<i>Pseudomonas fluoresces</i>	2.0	Aquatic
ANTITRANSPARANT			
Haven	Stearyl alcohol	1.0	Vegetables, fruit
TOTAL		18.6	

Product management strategies

MBI markets its products to be either used in a variety of ways, which include:

- Used to reduce or replace one or more chemicals (Regalia Rx, Grandevo, Venerate)
- Used where chemicals cannot be used (Regalia Rx, Grandevo, Venerate, Majestene)
- Added to an existing program (Regalia Rx)

DISTRIBUTION

MBI distributes Regalia through Koch Industries and its other products through its current distribution partners, which include several distributors focusing on the organic market.

PRODUCT DEVELOPMENT

MBI states that it has a proprietary product development process, including:

- A process that increases the active natural compounds produced by the product candidate
- A proprietary fermentation process

MBI acquired a manufacturing plant located in Bangor, MI, in July 2012, and renovated the location. Production was initiated in December 2013 with the company's flagship bioinsecticide, Grandevo.

During 2014, the company began revitalizing and expanding the manufacturing facility in multiple phases, with an anticipated total capital expenditure of \$32 million for larger fermenters to accommodate multiple products at higher volumes.

In 2016, Marrone Bio Innovations, Inc. and Groundwork BioAg, Ltd announce a collaboration to create and commercialize the world's first all-biological comprehensive seed treatment. The treatment is expected to contain a mycorrhizal biostimulant from GBA, as well as a bioinsecticide, a bionematicide, and a biofungicide from MBI. During 2016, Albaugh, LLC, and Marrone Bio Innovations, Inc. announced that the companies have signed an exclusive agreement to develop and market one of MBI's microbial products, a proprietary microbial biopesticide with insecticidal and nematocidal properties, for seed treatment applications.

In 2016, Marrone Bio Innovations, Inc. announced that the company has received registration of MBI-601 EP, a biofumigant, from EPA. This new product controls and suppresses plant parasitic nematodes, insect pests, and soil-borne plant diseases in agricultural and horticultural soils. The active ingredient, a strain of *Muscodor albus*, produces volatile compounds that either kill or inhibit the growth of certain destructive nematodes, pest insects, and also plant diseases, such as Fusarium root rot, damping off, southern blight, and Verticillium wilt, in addition to soil applications.

In 2017, Marrone Bio Innovations Inc. and Evogene, announce that MBI will advance certain novel bacteria and Evogene-identified related proteins into MBI's bioinsecticide product development pipeline under their previously announced multi-year collaboration for the discovery and development of novel insect control solutions.

STRATEGIC OUTLOOK TO 2021

Marrone Bio Innovations currently has several commercial products with significant market opportunities in the United States and internationally.

The company has a strong pipeline of new products ready to be launched within the next two years.

MBI has partnerships with strong, recognized distribution and development partners, a key to meeting its strong growth objectives.

MBI has a very solid R&D platform with a valuable library of patents and intellectual property.

MGK (VALENT-SUMITOMO)

SALES REVIEW

MGK has biopesticide sales totaling \$16 million in 2016, an increase of 9.5% from 2014 sales of \$13.4 million.

U.S. BUSINESS HIGHLIGHTS

Based in Minneapolis, MN, MGK is a family-owned insect control products company that recently became majority-owned by Sumitomo. Sumitomo also controls Valent Corporation and Valent BioSciences, and the sales of MGK are included in Valent.

MGK's biopesticide product line consists of two active ingredients:

- Pyrethrins
- Azadirachtin

HISTORY/OWNERSHIP STRUCTURE

MGK was founded in 1902 by Alexander McLaughlin; its principal business was grinding spices such as cinnamon and pepper, as well as plant leaves, barks, fruits, and flowers used in pharmaceuticals. In 1908, the firm was incorporated with partners George King and John Gormley, and by 1915 MGK was importing a variety of botanicals, including pyrethrum. In the 1920s, MGK hired Charles Gnadinger, a chemist with the U.S. Food and Drug Administration, to conduct investigations into the standardization and MGK's work on the refining of pyrethrum. Because of Gnadinger's brilliant work on extraction, MGK consistently offers high-quality pyrethrum-based insecticides suitable for household and industrial pest control. After World War II, MGK began to develop products with synthetic pyrethroids; complementing their pyrethrum products. The company acquired rights to the synergist MGK 264, which enhances the activity of insecticide ingredients and allows their use at reduced levels. MGK also developed a variety of insect and animal repellents widely used in consumer and industrial products.

In 2012, Sumitomo Chemical purchase of additional MGK shares raises its ownership stake in MGK to 76.36%, up from 32.88%, following an agreement with the Gullickson family, the founders and previous majority shareholders of MGK. It has now become a consolidated subsidiary of Sumitomo Chemical.

AGREEMENTS, JOINT VENTURES, ETC.

In October 2014, MGK and Valent U.S.A. (another Sumitomo subsidiary) entered into a marketing agreement to grow sustainable agriculture brands across the United States. Under the agreement, Valent would manage the marketing and sales of MGK's crop protection line of insect control products within the United States, beginning April 1, 2015.

At about the same time, MGK took over the consumer business of Valent Environmental Science.

R&D

MGK manages R&D internally through its team of chemists and entomologists, who are responsible for:

- Product analysis
- Biological testing
- Custom formulations

MGK chemists have developed a way to refine its pyrethrum, making its PyGanic products OMRI- & NOP-compliant. Many pyrethrum-containing products include the synergist Piperonyl Butoxide (PBO), which is not allowed in organic production.

Business summary 2016

MGK is the only pyrethrum supplier in the United States that refines its own pyrethrum. The company has total control over the processes used in refining and has engineered new ways to produce pyrethrum so it meets organic standards.

Now handled by Valent, MGK's bioinsecticide product line targets the cereal grain crop markets.

MGK's two formulations of Pyganic are labeled for use within the specialty fruit and vegetable markets. MGK also sells products for mosquito control and professional pest control, livestock and poultry, and consumer.

All bioinsecticide products are labeled for greenhouse and nursery use of specialty fruit and vegetable crops and flowers and foliage plants.

U.S. SALES

Table 109: MGK's Biopesticide Sales in the United States, End-user Level, 2016

Line item	\$ Million
Total crop market sales	13.0
Total professional (non-crop) sales	3.0
Total	16.0
Estimated.	

MGK's biopesticide sales are all classified as insecticides, with no other product types included in their portfolio.

PRODUCT LINE ANALYSIS

MGK's bioinsecticide product line consists of the following products:

Table 110: MGK's Biopesticide Product Sales in the United States, End-user Level, 2014

Major brand	Active ingredient	\$ Million	Target markets
INSECTICIDES			
Azera	Azadirachtin	2.0	Specialty fruits and vegetables, cereal grains
PyGanic EC 1.4	Pyrethrins	5.0	Specialty fruits and vegetables, cereal grains
Pyrellin	Pyrethrin	5.0	Specialty fruits and vegetables
Pyrocide	Pyrethrin	-	Pest Control
Riptide	Pyrethrin	1.0	Mosquito misting
Evergreen	Pyrethrin	3.0	Pest control/animals
All other		-	Pest control, mosquito
TOTAL		16.0	

MGK has seen growth due to the interest in biopesticides and the emergence of misting systems to control mosquitos in residential settings.

DISTRIBUTION

MGK crop protection products are available nationally through select distributors:

- Brandt/Monterey Ag
- Crop Production Services (CPS)
- Helena Chemical
- Wilbur-Ellis
- WinField Solutions
- ProKoz
- Spekoz
- VWR

MGK products are also available East of the Rockies through local specialty ag dealers.

STRATEGIC OUTLOOK TO 2021

MGK's sales are expected to continue their growth over the forecast period as they are well-positioned to participate in the demand for biopesticide products.

MONSANTO

SALES REVIEW

Table 111: Monsanto Sales Summary in the United States, 2014 to 2016

	\$ Million		
	2014	2016	Change, %
GLOBAL SALES SUMMARY			
Corporate global	15,575	13,502	(13.3)
Corporate U.S.	8561	7305	(14.7)
Global crop protection	5,115	3,514	(31.3)
Global seed	10,740	9,988	(7.0)
U.S. CROP PROTECTION CHEMICALS			
Crop markets	1,625	1,358	(16.4)
Professional markets	235	198	(15.7)
Seed treatments	310	270	(22.6)
Total	2170	1826	(15.8)
U.S. BIOPESTICIDE SALES-a	29.0	28.6	(0.4)
a- Biopesticide sales include crop and professional markets at end user level.			

U.S. BUSINESS HIGHLIGHTS

U.S. biopesticide crop protection sales for Monsanto decrease 5.5% during 2016 to \$28.6 million.

Monsanto is a publicly traded American multinational agrochemical and agricultural biotechnology corporation headquartered in St. Louis, MO. Monsanto refers to its biopesticide business as “biological,” but in keeping the consistency within this report, the segment will be referred to as “biopesticides.”

The latest addition to the company’s research and development efforts is the company’s agricultural biopesticide platform, labeled as “BioDirect” technology.

BioDirect involves the development of products that engage a naturally occurring process called RNA interference (RNAi).

Monsanto's entry into the biopesticides market began in 2013 when the company announced a long-term strategic alliance with Novozymes.

In May 2016, Bayer also announced that Bayer and Monsanto have signed a definitive agreement under which Bayer acquires Monsanto for USD 128.00 per share in an all-cash transaction. Based on Monsanto's closing share price on May 9, 2016, the day before Bayer's first written proposal to Monsanto, the offer represents a premium of 44% to that price. While there is resistance to completing this deal, it would greatly transform the ag market. It is unclear how Monsanto's alliance with Novozymes will be impacted by this purchase.

The alliance was developed to transform Monsanto's research and commercialization of sustainable microbial products that will provide a new platform of solutions for growers around the world. Novozymes is a global biotechnology company headquartered in Bagsvaerd, Denmark, employing approximately 6,300 people. Novozymes participates in a variety of industries including, agriculture, bioenergy, biopharma, food and beverage, household care, leather, pulp and paper, textile, and wastewater solutions.

In February 2014, the companies dubbed its new collaboration platform, The BioAg Alliance. The BioAg Alliance is expected to expand the research and commercialization of a new generation of microbials to help farmers meet the world's demands for food and feed in a sustainable way.

Novozymes is a leader in microbial solutions that represent a significant part of the agricultural biologicals industry. Global microbial sales within the industry represent an estimated \$2.3 billion in annual sales and has posted mid-teens sales growth during each of the last several years. Microbial-based solutions are derived from various naturally-occurring microorganisms, such as bacteria and fungi.

ACQUISITIONS

During 2013, Monsanto purchases select assets of Agradis, Inc., a privately-held company focused on developing sustainable agricultural solutions. The purchase includes the Agradis name and its collection of microbes that can improve crop productivity. Monsanto also acquires the company's R&D site in La Jolla, CA. Total cash paid for the acquisition was \$85 million.

MONSANTO: NOVOZYMES COLLABORATION DETAILS

Monsanto's and Novozymes strategic alliance, named The BioAg Alliance, brings together Novozymes' capabilities for discovering, developing, and producing microbes, and Monsanto's discovery capabilities, field testing, and market research.

Table 112: Details of the BioAg Alliance, Monsanto-Novozymes Collaboration

Focus	Microbial solutions leap forward as one of the important "beyond-the-seed" technologies, providing more tools for farmers globally to drive yield and sustainability in agriculture
	Establishment of a joint technology and commercialization alliance that combines the expertise of both companies to create Industry-First Microbial Platform
Discovery	Each company maintains independent discovery programs to generate leads for joint R&D pipeline
Development	Projects are jointly funded at 50-50 cost sharing through each phase of development: Joint R&D application development
	Monsanto serves as lead for field testing, registration and commercial-track development
Manufacturing	Novozymes serves as lead for fermentation, up-scaling and manufacturing
Commercialization	Current and emerging products are commercialized globally by Monsanto through global commercial channels. Value from commercialization is shared at 50-50
	Novozymes' commercial organization and marketing responsibility for Novozymes' current product portfolio in agricultural biologicals will be transferred to Monsanto
	Monsanto will pay Novozymes an aggregate upfront cash payment of \$300 million net in recognition of their ongoing business and capabilities in microbials, and for Novozymes to supply alliance products
SOURCE: Monsanto, The BioAg Alliance: Unleashing the Potential of Microbial Solutions in Ag, a Joint Media Announcement. December 10, 2013.	

R&D

During 2016, Novozymes and Monsanto conducted research across 170,000 field trial plots in 70 locations throughout the United States, and the companies expect to more than double the number of research field plots next season.

Novozymes is to open new research and development center in the United States dedicated to its bioagriculture business. The new facility will be located near the Research Triangle Park in Cary, NC, where the company will invest \$36 million over the next three years and create 100 new research and development jobs. In 2016, Monsanto announces its commitment to develop and commercialize innovative microbial solutions for farmers through The BioAg Alliance. In December 2016, Monsanto and Novozymes share details of their newest product, the corn inoculant Acceleron B-300 SAT. Derived from a fungus found in soil, Acceleron B-300 SAT showed a two-year average yield advantage of more than 3 bushels per acre. The Acceleron B-300 SAT inoculant will be applied to all of Monsanto's new 2017 corn hybrids sold in the United States. Acceleron B-300 SAT increases plants' ability to take up nutrients, and is an improved formulation of the JumpStart inoculant (*Penicillium bilaiae*).

In 2016, Valent BioSciences Corporation (VBC) announces that it has reached an agreement with The BioAg Alliance to distribute certain Actinovate Biological Fungicide products. Through the agreement, Actinovate AG brand sales for the United States will be handled through Valent U.S.A. Corporation, and for Canada by Valent Canada, Inc. Actinovate AG is a broad spectrum biofungicide product for the management of common foliar and soilborne diseases found on outdoor crops and in greenhouses, nurseries, and turf. In 2016, Monsanto Company (NYSE: MON) announces that EPA has approved XtendiMax^M herbicide with VaporGrip Technology, a low-volatility dicamba herbicide, for in-crop use with Roundup Ready 2 Xtend soybeans and Bollgard II XtendFlex cotton. This significant milestone will provide farmers the opportunity to utilize dicamba in the Roundup Ready Xtend Crop System in 2017. In May 2017, Monsanto Company (NYSE: MON) announces that the U.S. EPA issued registration for tiozafafen, which is branded as NemaStrike Technology. This approval will enable farmers to realize the nematode control benefits of the technology in 2018, pending state approvals.

U.S. SALES

In 2016, Monsanto agrees to distribute Actinovate through Valent, so the actinovate sales are now attributed to Valent. Monsanto also stopped actively distributing Met-52 and is currently looking for a distribution partner. These moves effectively removed Monsanto's from the non-crop market.

Table 113: Monsanto's Biopesticide Sales in the United States, 2016

Line item	\$ Million
Total crop market sales	28.6
Total professional (non-crop) sales	-
Total	28.6
Estimated.	

Table 114: Monsanto's Biopesticide Sales Summary in the United States by Crop Market, End-user Level, 2014 and 2016

	\$ Million			
Product group	2014	2016	% Change	% Of total
Inoculants-a	22.5	28.6	6.1	100.0
Insecticides	2.5	-	-	-
Fungicides	4.0	-	-	-
Total	29.0	18.6		100.0
a- Includes isoflavonoids and lipo-chitooligasaccharide.				

PRODUCT LINE ANALYSIS

For the sake of this analysis, all the Monsanto/Novozymes product sales distributed by Monsanto will be attributed to Monsanto. Actinovate will be attributed to Valent.

Monsanto/Novozymes separate their products into three categories:

- Biofertility products that increase the supply of nutrients to crops
- Bioyield enhancement products which stimulate crop stress resistance and generally improve crop health and productivity
- Biocontrol products that control insects, disease, and weed pests

Biofertility products

Biofertility products include:

- JumpStart and JumpStart LCO
- TagTeam and TagTeam LCO
- Optimize
- Cell-Tech
- Nitragin Gold

Bioyield enhancement products

Bioyield enhancement products include:

- Cue
- Revv
- Torque

Table 115: Monsanto's Biopesticide Product Sales in the United States, End-user Level, 2016

Major brand	Active ingredient	\$ Million	Target market(s)
INOCULANTS			
Quickroots	Bacillus subtilis and amyloliquefaciens FZB24	7.5	Inoculant for use with ag seeds, plants or mixtures of soil media
Jumpstart	Penicillium bilani	2.0	Corn, canola, wheat, legumes
TagTeam LCO		2.0	Soybeans, peas, lentils
Optimize		17.0	
Cell-Tech	Rhizobium (nitrogen fixation)	-	Pea/lentil, soybeans, peanuts, garbanzo beans
Nitragin Gold	Sinorhizobium meliloti	-	Alfalfa, clover
BIOYIELD ENHANCERS			
Cue	Isoflavonoids	-	Soybeans
Revv	Isoflavonoids	0.1	Cotton
TOTAL		28.6	

U.S. BUSINESS REVIEW

U.S. organizational structure

Under the BioAg Alliance agreement, Monsanto will be responsible for all Novozymes commercial organization and marketing for its agricultural biologicals. Valent distributes its products in the Greenhouse/Nursery markets.

FIELD SALES ORGANIZATION

Within the AgBio Alliance, Monsanto is responsible for the sales of current and emerging products. Products are commercialized through U.S. and international commercial channels. Valent BioSciences Corporation (VBC) announced it has reached an agreement with The BioAg Alliance to distribute certain Actinovate Biological Fungicide products. Through the agreement, Actinovate AG brand sales for the United States will be handled through Valent U.S.A. Corporation and for Canada by Valent Canada, Inc.

Monsanto is currently using its established field sales personnel to market the microbial product line.

PRODUCT DEVELOPMENT

Under the BioAg Alliance between Novozymes and Monsanto, projects are jointly funded on a 50-50 cost sharing basis through each phase of development. Joint R&D application development will be conducted. Monsanto serves as the lead for field testing, registration, and commercial-track development.

They have several projects underway, including:

The Corn BioYield 2 project combines Acceleron B-300 SAT with the signal molecule LCO (lipochitooligosaccharide) to enhance natural growth processes such as root and shoot development and improve nutrient uptake. Corn BioYield 2 strains have delivered up to an average of 5 bushels per acre yield increase in 2016 field trials. Estimated launch: 2019.

The Corn BioYield 3 project encompasses The BioAg Alliance's tests on multiple microbial strains for a new corn inoculant. The leading strains have shown to increase yields by more than 3 bushels per acre. Corn BioYield 3 is anticipated to be the first product invented and developed from discovery to launch through The BioAg Alliance.

The Soy BioNematicide project is expected to provide an additional tool for growers to control nematodes, microscopic parasitic worms that damage plants. This microbial product is expected to show activity against different nematodes, including soybean cyst nematode. The Alliance will continue field tests to confirm efficacy in combination with a range of other chemical and biological seed treatments.

MANUFACTURING

Novozymes is responsible for all fermentation, up-scaling and manufacturing of all Monsanto biopesticide products.

SUMMARY OF U.S. MARKET POSITION

Monsanto has completed its third year of its BioAg Alliance, its partnership with Novozymes to boost research and commercialization of sustainable microbial technology, and new products are coming out of the alliance. It has separated the distribution of products to the nursery/greenhouse market as Monsanto had little presence there.

Through the BioAg Alliance Monsanto gains various advantages, which include:

- Access to Novozymes leading biopesticide products
- Its own independent research with access to Novozymes new developments
- Field testing, registration, commercialization of all new products

Monsanto currently holds the number seven spot among U.S. biopesticide manufacturers, falling from number 3. The company will likely have a positive growth year in 2017 as new products are introduced through its BioAg Alliance.

STRATEGIC OUTLOOK TO 2021

Monsanto is well-positioned to participate in the growing biopesticide market in the coming years through the growth of the BioAg and Agradis businesses. New products from the BioAg business are expected to hit the market in 2017 which will enhance their growth. It will be interesting to see if Monsanto positions its new nematocide to replace the bionematicide Votivo, or if it repositions Votivo for fields with low nematocide pressure.

NOVASOURCE

SALES REVIEW

Table 116: NovaSource's Sales Summary in the United States, 2014 to 2016

	\$ Million		
	2014	2016	Change, %
GLOBAL SALES SUMMARY			
Corporate global	1,649	1,828	3.7
Corporate U.S.	-	639	5.0
Global crop protection	92	95	4.5
U.S. CROP PROTECTION CHEMICALS			
Crop markets	22	22	-
Professional markets	1	1	-
Total	23	23	-
U.S. BIOPESTICIDE SALES-a	3.1	3.5	12.9

a- Biopesticide sales include crop and professional markets and are stated at end user level.

U.S. BUSINESS HIGHLIGHTS

U.S. biopesticide sales for NovaSource increase 12.9% during 2016 to \$3.5 million.

NovaSource was formed in 2005 as a generic crop protection chemical business unit, with a strategic focus on specialty fruit and vegetable markets.

NovaSource is a business unit of Tessenderlo Kerley Inc. (TKI), part of the Tessenderlo Group based in Belgium. NovaSource is the North American division of the Tessenderlo Group.

NovaSource's Phoenix, Arizona office manages sales in the United States, Mexico, and Latin America.

NovaSource's biopesticide product line is based on two main products:

- Surround, based on calcine kaolin film which protect the fruit against direct sunburn and heat stress damage
- Lime Sulfur with the active calcium polysulfide

NovaSource is the primary crop protection supplier for sunburn protectant products (kaolin and calcium carbonate), with more than 50% market share. TKI purchased the global assets of the Purfresh crop protection product line in August 2011, including Purshade calcium carbonate sunburn protectant products. TKI also purchased Sinbar (terbacil) from DuPont in February 2011.

U.S. CROP PROTECTION BUSINESS

Business summary 2016

NovaSource currently has two active ingredients built around its biopesticide product brands.

The following products target the specialty fruit and vegetable markets:

- Surround (insecticide)
- Lime Sulfur (fungicide)

Surround WP is marketed towards the nursery and greenhouse markets in addition to agricultural crops.

U.S. SALES

NovaSource has sales totaling \$3.5 million in 2016 from their insecticide and fungicide products.

Table 117: NovaSource's Biopesticide Sales Summary in the United States by Crop Market, End-user Level, 2014 and 2016

	\$ Million				
Product group	2014	2016	Change	% Change	% Of total
Fungicides	1.1	1.8	0.7	63.6	51.5
Insecticides	2.0	1.7	(0.3)	(15.0)	48.6
Total	3.1	3.5	0.2	12.6	100.0

U.S. BUSINESS REVIEW

Growth of NovaSource's biopesticide products for the fruits and vegetables business will be limited to expansion with existing products. Surround WP is marketed towards the nursery and greenhouse markets in addition to agricultural crops.

SUMMARY OF U.S. MARKET POSITION

NovaSource's biopesticide product line is limited, with just three products; however, sales are substantial at \$3.5 million.

The company has a strong relationship with established national distributors that are marketing its products well to the growers that need them.

STRATEGIC OUTLOOK TO 2021

NovaSource's five-year outlook within the biopesticide segment is questionable; however, the company's parent, TKI, may support growth plans for this growing segment of the industry. Surround WP and Lime Sulfur are expected to show moderate growth over the forecast period.

NUFARM BIOPESTICIDES

SALES REVIEW

Table 118: Nufarm's Sales Summary in the United States, 2014 to 2016

	\$ Million		
	2014	2016	Change, %
GLOBAL SALES SUMMARY			
Corporate global	2,622	2,791	15.1
Corporate U.S.	450	582	5.7
Global crop protection	2,480	2,647	16.1
Global seed	-	143	-
U.S. CROP PROTECTION CHEMICALS			
Crop markets	270	255	(5.6)
Professional markets	100	100	-
Seed treatments	25	17	(32)
Total	395	372	(5.8)
U.S. BIOPESTICIDE SALES-a	4.3	15.0	249
a-Biopesticide sales include crop and professional markets and are stated at end user level.			

U.S. BUSINESS HIGHLIGHTS

Nufarm's U.S. biopesticide crop protection sales increase 249% during 2016 to \$15 million.

The company refers to its biopesticide business as "biorationals." Nufarm introduced its portfolio of biorational products in 2012.

According to Nufarm its North America business benefited from a stronger portfolio of biorational products in 2016.

OWNERSHIP STRUCTURE

Nufarm is a crop protection chemical company with headquarters in Melbourne, Australia. The company holds more than 2,100 product registrations, and markets products in more than 100 countries around the world.

The company is listed on the Australian Stock Exchange with the symbol, "NUF".

Sumitomo has a 23% stake in Nufarm.

ACQUISITIONS/EXPANSIONS

The company finishes completion on its new North American headquarters and manufacturing plant in Alsip, IL. The new facility opened in February 2013, and includes the global head office for the group's Seed Technologies business.

Nufarm completes work on its new Science and Innovation Center near Sacramento, CA, to help support innovation and growth in its seed business.

Nufarm acquires Cleary Chemical Corporation of Dayton, NJ, a marketer of plant protection chemicals to the turf and ornamental (T&O) markets. Nufarm will offer the entire line of Cleary products under the Cleary brand name until the company integrates the two businesses. Over the past three years Nufarm has rationalized its manufacturing, closing plants in Canada and Australia.

LICENSE/AGREEMENTS/JOINT VENTURES: UNITED STATES

In May 2014, Nufarm enters into an agreement with U.S. crop protection nutrition company, Verdesian Life Sciences, to distribute Verdesian's biopesticide Bloomtime in the United States and Canada. Bloomtime is a bioherbicide containing the active ingredient pantoea agglomerans strain E325 and is used to combat downy brome, commonly known as cheatgrass, in cereal crops, grass seed, and alfalfa.

Nufarm and Valent signed agreement that appointed Nufarm as the exclusive distributor of its branded products for professional turf, ornamental, and aquatic use in the United States, effective February 16, 2014.

LICENSE/RESEARCH/JOINT VENTURES: INTERNATIONAL

Nufarm announces exclusive partnership with Israeli-based technology firm, Phytech, to develop new plant monitoring technology in Australia and New Zealand. The system provides real time monitoring via mobile in-field devices on a range of parameters that allow growers to optimize inputs and make other decisions that impact on both the quality and yield of their crops.

U.S. SALES

Nufarm total biopesticide sales in 2016 is estimated at \$15 million, an increase of 269% from 2014 levels. Nufarm's biopesticide sales were for fungicides and plant growth regulators (PGRs).

PRODUCT LINE ANALYSIS

Nufarm has greatly expanded its biopesticide portfolio over the past two years and it now contains nine biopesticide actives, including three PGR's and four fungicides.

Several of Nufarm's products are sourced directly from other manufacturers or distributors, and include the following:

- Fungiphite (Verdesian Life Science)
- Phorcephite (Loveland Products)
- Propht (Helena)
- Rampart (Loveland Products)
- Reveille (Helena)

The majority of Nufarm's biopesticide products target the specialty fruit and vegetable crop or turf and ornamental markets.

With \$15 million in sales and 1.9% of the U.S. biopesticide market, Nufarm remains a strong player within the industry. The company is very experienced at bringing new products to the market, and it is expected to continue ramping up its sales within this sector of the U.S. crop protection market.

Table 119: Nufarm Biopesticides Sales in the United States by Active, End-user Level, 2016

Brands	Actives	Crops	\$ Million
Fireline, Mycoshield	Oxytetracycline	Fruits	5.5
Agri Tin	Tin	Vegetables, fruits	2.5
Fungiphite, Phorcephite, Phostrol, Prophyte, Reville	Phosphoric acid	Vegetables	2.5
AS-50, Agrimycin	Streptomycin	Seed treatment	1.5
Champ	Coper Hydroxide	Vegetables, fruits	1.0
Progibb, Gibpro, Ritesize	Gibberillic acid	Greenhouse/turf, fruit	1.0
Microsulfur	Sulfur	Vegetables, fruits	0.75
BlightBan, Bio-Cure-B	Pseudomonas fluorescens	Fruits	0.25
Total			15.0

STRATEGIC OUTLOOK TO 2021

Nufarm's generic strategy now encompasses all major market segments of the crop protection industry:

- Seed/genetics/traits
- Field crop chemicals
- Specialty crop chemicals
- Seed treatments
- Specialty professional markets (T&O), vegetation management
- Biopesticides

They have greatly expanded their product offering over the past two years through partnerships with other companies and it is expected that it will continue with this strategy.

PLANT HEALTH CARE (PHC)

SALES REVIEW

Table 120: Plant Health Care Sales Summary in the United States, 2014 to 2016

	\$ Million		
	2014	2016	Change, %
GLOBAL SALES SUMMARY			
Corporate global	7,055	6,329	(5.4)
U.S. BIOPESTICIDE SALES-a,b	2.7	2.7	-
a- Biopesticide sales include crop and professional markets and are stated at the end-user level.			
b- Includes PHC's patented Harpin technology.			

U.S. BUSINESS HIGHLIGHTS

U.S. biopesticide crop protection sales remain flat at \$2.7 million.

Plant Health Care (PHC) is a provider of scientifically proven biological products for the agricultural industry. The company offers products to improve the health, vigor, and yield of major field crops, as well as specialty fruit and vegetables. The company states that all of its products are patent protected.

The company has focused on selling or licensing its technologies in global agricultural markets in order to achieve the greatest return for its stakeholders.

PHC main office is in Raleigh, NC.

PHC, established in 1995 in Pittsburgh, PA, and moved the company's headquarters to Raleigh, NC, in 2013.

The company's product portfolio contains two proprietary technologies: Harpin and Myconate.

OWNERSHIP STRUCTURE

On July 6, 2004, the company was successfully floated on the AIM market of the London Stock Exchange, raising \$8.5 million to fund product and company acquisitions and expand its sales and marketing team. In April 2013, the company raised \$20.3 million through a Placing and Subscription of ordinary shares of stock.

LICENSE/AGREEMENTS/JOINT VENTURES: UNITED STATES

In 2013, the company signed a development and commercialization agreement with Arysta LifeSciences for the foliar use of Harpin in several crops, in a number of geographies. The first fruit of the collaboration was the U.S. launch in 2014 of “Astera with appro,” a mixture of Harpin with the fungicide propiconazole.

PHC is currently active in negotiations to secure commercial agreements for both Harpin and Myconate technologies, with at least one expected to be completed by the end of 2014.

In 2016, Plant Health Care, Inc. and Talc U.S.A. announced that they have reached agreement on the distribution of a new product for the U.S. corn market. The new product, Inceptive, will be marketed and sold by Talc U.S.A. and will contain Plant Health Care’s patented Harpin $\alpha\beta$ technology. Talc U.S.A., a leading supplier of seed lubricants and inoculants in the US corn market, has a network of over 1,500 dealers servicing the U.S. corn market. Plant Health Care’s Harpin $\alpha\beta$ technology has proven benefits for corn growers; together creating outstanding market synergy.

R&D

R&D activity takes place in the company’s premises in Seattle, WA. The chief science officer is Dr. Zhongmin Wei.

In 2014, the company increased its investment in R&D, which has allowed acceleration in its work on Harpin technology and additional work on its PREtec technology platform. PHC has developed a series of peptides that mimic the activity of Harpin protein and should be easier to formulate into different pesticide combinations.

PHC continues to work with Arysta Life Science for additional product launches outside its agreement for Arysta’s “Astera with appro” fungicide.

The company bases its sales and marketing activities around the company's mission. PHC's mission is to provide novel natural-based products to the global agriculture industry to help feed the world.

LICENSE/RESEARCH/JOINT VENTURES: INTERNATIONAL

PHC enters into a development and distribution agreement with Sipcam Italia S.P.A. Under the agreement, Sipcam will develop and market proprietary PHC technologies for use on certain crops in Italy.

U.S. CROP PROTECTION BUSINESS

PHC has a portfolio of established products based on its proprietary Harpin and Myconate technologies. Harpin-based products are well-established in both the seed and foliar treatment markets, and have been applied on more than 10 million acres of crops worldwide. Myconate is a proven product, with sales currently limited to certain niche markets, but with the potential for modest growth.

U.S. SALES

Plant Health Care's biopesticide sales are primarily made up of their Harpin Technology. All of the sales are to the crop protection markets.

Table 121: Plant Health Care's Product Group Sales Summary in the United States by Crop Market, End-user Level, 2014 and 2016

	\$ Million				
Product group	2014	2016	Change	% Change	% Of total
Harpin Technology-a	2.7	2.7	-	-	99.0
All other-b	<1	<1	-	-	1.0
Total	2.7	2.7	-	-	100.0

a- Plant Health Care's patented technology.

b- Includes PHC's Myconate soil treatment.

PRODUCT LINE ANALYSIS

PHC separates its products into two technology categories:

- Harpin technology, protein technology that triggers growth and self-defense mechanisms within plants, stimulating more robust plant health and fruiting, which increases yield
- Myconate technology soil amendments that are proven to help many crops produce better yields

Harpin has seen applications on more than 10 million acres of crops around the world, with demand continuing to build in the field.

Field crops

PHC's product ProAct is for use on field crops and works by triggering a complete systemic acquired response (SAR) throughout the plant. The plant reacts as if it is under attack from a pathogen, but it is only a false alarm. The plant quickly increases its photosynthesis and energy to fight back. The extra energy and strength that the plant creates is used to reduce stress levels, and increase production and quality, resulting in higher profits for growers.

Research has also shown that after a ProAct application, the plant builds up its defense system to fight off nematodes by reducing nematodes feeding, an added benefit in fields with nematode problems.

Specialty crops

PHC's product for the specialty crops is its Employ plant health promoter.

Employ stimulates the plants natural growth and defense systems leading to one or more of the following benefits:

- Improved stand
- Suppression of nematode egg production
- Increased marketable yield
- Enhanced quality
- Extended shelf life
- Improved transplant recovery

Seed treatment

N-Hibit seed treatment contains the Harpin technology and is marketed as “all-natural”, without containing living organisms. It can be applied to seed as far ahead of time before planting as is deemed to be useful, and it will remain viable on the seed until the seed is planted.

The company’s Myconate product can be applied as a seed treatment, either as a fine, dry powder (Myconate HB) for the hopper box, or as an aqueous suspension (Myconate AS) for seed coating. Myconate for use as a seed treatment can be used on a very wide range of agricultural crops including cereals, corn, cotton, soybean, sorghum, sunflower, peanut, field beans and rice. Myconate can also be used in a broad range of vegetable crops, including carrots, lettuce, onion, pepper, tomato, peas, beans, and cucurbits.

Soil treatment

PHC’s Myconate mycorrhizal is a stimulant product with the objective to treat the soil near the plant’s roots in order to increase the growth and colonization of roots by beneficial vesicular-arbuscular mycorrhizal (VAM) fungi. Myconate can be applied in-furrow for row crops, either alone or in combination with starter fertilizer and can also be applied as a soil drench, as a transplant dip or through an irrigation system.

Table 122: Plant Health Care’s Product Line for Crop Markets in the United States, End-user Level, 2014 and 2016

Major brand	Active ingredient	\$ Million		Target market(s)
		2014	2016	
N-Hibit Gold CST	Harpin protein	2.7	2.7	Seed treatment crop markets
Messenger		-	-	Various crops
Proact		-	-	Field crops
Employ		-	-	Specialty fruit, vegetables
Myconate ST	formononetin	<1	<1	Ag, vegetable crops (seed treatment)
Total		2.7	2.7	

U.S. BUSINESS REVIEW

PHC markets itself as a technology licensing business and looks primarily to manufacturers of crop protection products to apply their technology to new or existing product lines.

PRODUCT DEVELOPMENT

PHC's two technologies are patent protected, and any future products developed by the company are expected to be under patent as well.

The company is currently developing a third generation of its Harpins technology. The question remains if its two patented technologies are enough to sustain even a small company of this size within the competitive global crop protection market.

THE SCOTTS MIRACLE-GRO COMPANY

OVERVIEW

The Scotts Miracle-Gro Company traces its roots to O.M. Scott & Sons, which was founded in 1868 by O.M. Scott in Marysville, OH, as a premium seed company for the U.S. agricultural industry.

O.M. Scott & Sons focused on providing cost-effective weed-free grass seeds to home gardeners. In 1928, O.M. Scott & Sons launched Turf Builder, the first fertilizer formulated specifically for lawns.

Beginning in the early 1990s, Scotts began an aggressive expansion campaign to diversify within the lawn and garden industry and gain market share, both domestically and internationally.

In November 1992, the company purchased Republic Tool & Manufacturing Corp. of Carlsbad, CA. At the end of 1993, Scotts bought Grace/Sierra Horticultural Products of Milpitas, CA, another leading supplier of consumer and professional horticultural and turf-care products, which gave the company a worldwide presence. Scotts' most important acquisition took place in 1995. Through an exchange of \$195 million worth of equity, the company purchased Stern's Miracle-Gro Products Inc., a company which had been formed in Long Island, NY, by Horace Hagedorn and Otto Stern in 1951. The merger companies continued to be headquartered in Ohio. In 1998, in the United States, Scotts acquired the organics company EarthGro, Inc., the Northeast region's leading organic company. This acquisition strengthened the company's services to mass retailers, home centers, and independents in the Northeast region.

In fiscal 1999, the company acquired the Ortho brand from Monsanto, and exclusive rights to market and distribute the consumer Roundup product line to the lawn and garden market in the United States, the United Kingdom, and other selected countries.

In 2011, The Scotts Miracle-Gro Company and Marrone Bio Innovations (MBI), announced exclusive research and development agreement designed to provide consumers new natural plant protection products. Under terms of the deal, ScottsMiracle-Gro will have access to MBI's full portfolio of innovative biopesticides for the development of new products for the lawn and garden market. The two companies collaborate on research and development efforts, and MBI manufactures and supplies any resulting products, while ScottsMiracle-Gro maintain worldwide marketing rights. Financial terms of the deal were not disclosed.

In 2015, Scotts Miracle-Gro Co. spent about \$130 million to buy California's General Hydroponics Inc., marking the company's largest acquisition since a European expansion push in the 1990s. Scotts also acquired the sister company, Vermicrop Organics, marking Scotts entry into serving the cannabis industry.

In 2016, Scotts Miracle-Gro Co. bought Blossom, a smart water controller that reduces water and energy usage, and Oso, a water analysis device.

In 2016s, Scotts also spent \$136 million for buying Gavita, a Dutch grow lighting and hardware company, and announced a deal to buy Arizona-based Botanicare, a plant nutrient and hydroponics products provider that notched about \$40 million in sales.

BUSINESS STRATEGY AND OBJECTIVES

Scotts Miracle-Gro positions itself as a lawn and garden company that helps consumers succeed.

The company's vision is to be the world leader in the consumer lawn and garden industry, and it has made great strides to fulfill this vision. It has recently made a big move into the legal cannabis-growing market, buying several hydroponics, grow light and automation technology companies in the cannabis business.

Scotts Miracle-Gro leverages the strength of its brands as well as its merchandising and supply chain expertise for growth. Through acquisitions and internal product line extensions, Scotts Miracle-Gro has become the market leader in each of its major consumer lawn and garden categories in North America, France, the United Kingdom, and Germany.

With the sale of the Global Professional business in 2011, the company is presently divided into two reportable segments: Global Consumer, and Scotts LawnService. With the acquisition of General Hydroponics, it formed a third business segment focused on the cannabis cultivation business.

In the Global Consumer segment, the company manufactures and markets consumer lawn and garden products in certain categories: Lawn Care, Gardening and Landscape, and Home Protection.

The company's research and development efforts address improvement of existing products, development of new products, as well as potential changes in manufacturing, packaging, and delivery systems. Scotts Miracle-Gro holds an 80% interest in Sanford Scientific, a research-oriented company that specializes in genetic engineering of plants.

CONSUMER PESTICIDES AND FERTILIZERS

The company's research and development efforts address improvement of existing products, development of new products, as well as potential changes in manufacturing, packaging, and delivery systems. Scotts introduced the first home lawn fertilizer, Scotts Turf Builder, in 1928, and the first selective weed control and fertilizer combination product in 1947. The Home Protection category focuses on helping consumers protect their homes from pests and maintain external home areas. The insect and rodenticide products are marketed under the Ortho brand name, including insect control products under the Ortho Max and Bug-B-Gon Max sub-brands and rodenticides under the Home Defense Max sub-brand. The category's weed control products for hard surfaces are marketed under Ortho brand name, and non-selective weed control products under the Roundup brand name. With the purchase of Botanicare Scotts, it re-entered the professional specialty market with nutrients, soilless media, and biostimulants.

FACILITIES

The corporate headquarters located in Marysville, OH, own or lease around 750 acres of facility. In addition to the manufacturing, distribution, and R&D facilities in Marysville, the company leases office space for sales, marketing, and general operating activities, as well as warehouse space throughout North America and continental Europe, as needed. The Global Consumer business segment in North America uses the company's headquarters; two research facilities located in Apopka, FL, and Gervais, OR; and production facilities in Pearl, MS, and Fort Madison, IA. In addition, Scotts Global Consumer business operates 29 stand-alone growing media facilities in North America, 24 of which are owned by the company, and five of which are leased.

BIOPESTICIDE SALES

Biopesticides are sold under the Ortho Elementals master brand and are based on soybean oil, pyrethrin, fatty acids, and iron phosphate.

Table 123: Scotts Sales of Biopesticides to Consumer Markets Under the Ortho Elementals Brand in the United States, 2016

Active	Brand(s)	\$ Million
Pyrethrin combinations	Garden Insect Killer, 3-In-1 Rose & Flower Care	8.0
Iron phosphate	Slug & Snail Killer	8.0
Iron HEDTA	Lawn Weed Killer	7.0
Rose defense	Neem Oil	5.0
Neem concentrate	Azadirachtin	5.0
Soybean oil	Ant & Roach Killer, Home Insect Killer	4.0
Animal repellent	Peppermint oil, Garlic,	4.0
Potassium salts of fatty acids	Insecticidal Soap	3.0
Caster Oil	Mole and Gopher	3.0
Totals		53.0

The combination of the Scotts brands along with Tom Cat and Greenlight makes Scotts the fourth-largest biopesticides supplier in the United States.

VALENT (SUMITOMO)

SALES REVIEW

Table 124: Valent Sales Summary in the United States, 2014 to 2016

	\$ Million			
	2014	2015	2016	Change, %
GLOBAL SALES SUMMARY				
Corporate global	20,083	18,652	17,784	4.7
Corporate U.S.	540	505	496	1.6
Global crop protection	3,065	3,186	2,867	10.0
Global seed	-	-	-	-
U.S. CROP AND PROFESSIONAL CHEMICAL MARKETS				
Crop markets	385	398	421	5.8
Professional markets	35	40	43	7.5
Total	420	438	464	5.9
U.S. CROP PROTECTION				
Crop chemicals	365	371	395	6.5
Seed treatments	20	27	26	(3.7)
Total crop chemicals	385	398	421	5.8
Seed traits	-	-	-	-
Total	385	388	421	5.8
NORTH AMERICA CROP PROTECTION				
United States	385	388	421	5.8
Canada	25	30	32	3.3
Seed traits-a	-	-	-	-
Total	410	418	453	8.4
a- Seed trait sales, if applicable, include both United States and Canada.				

U.S. BUSINESS HIGHLIGHTS

Valent's U.S. crop protection (crop market) sales were up to \$421 million for 2016 versus \$388 million the previous year.

Valent has no biotech or seed presence in the United States, but the company has positioned its traditional line of products to exploit biotech trends as effectively as possible.

Sumitomo, Valent USA's parent company, acquires DuPont's Asana insecticide business in the United States. Asana will be distributed through Valent USA Corporation during 2016.

Valent signs an agreement with MGK to manage the marketing and sales of MGK's crop protection line of insect control products within the United States, beginning April 1, 2015. Products include PyGanic, Azera, Veteran D, Tersus, and EverGreen 60-6. The products will be added to Valent's agricultural portfolio.

A number of new products/registrations are introduced during the year:

- Presidio fungicide is registered for use in tobacco.
- Zeal SC Miticide is registered with a new liquid formulation that allows for quick mixing and easy loading.
- Registration is complete for its Intego Suite Soybeans, a new seed protectant to control multiple species of Pythium and Phytophthora.
- Valent introduces liquid formulation of Valor herbicide by the name of Valor EZ. The company terms it as a suitable residual partner with the Roundup Ready Xtend Crop System.
- Retain plant growth regulator is registered with the California Department of Pesticide Regulation for use in almonds.
- Zeal SC miticide gets registration from the US EPA for use in soybean. Zeal had earlier been registered for melons, field corn, and cotton.

The company expands its research and development footprint in North America:

- The Midsouth Agricultural Research Center (MSARC) will be expanded with an addition of compound characterization facilities, including greenhouses and environmentally controlled labs. The new facilities will allow year-round bioassay screening for the R&D pipeline.
- A new research facility, Midwest Agricultural Research Center (MWARC) near Champaign, IL. The new facility will be a center for agronomic research and training in field crop research. It will also be a test bed for commercial scale testing of new products and formulations.

Valent launches Intego Suite Seed Fungicide System for soybeans. The Intego Suite System contains the first new, novel seed protection fungicide chemistry, which contains dual modes of action that create a complete zone of protection around the seedling, above and below the ground.

Valent begins expansion plans for its North America portfolio. Plans include organizing sales and technical service teams into three commercial units: Western, Midwest, and Coastal. It also plans to expand its research infrastructure, to support the development of new pipeline technologies.

Valent is very active in the trade, sponsoring college agricultural programs. It launches an agricultural college scholarship contest. The company also expands its partnership with the national Future Farmers Association (FFA) Foundation.

Valent BioSciences and BioAg Alliance enter a supply agreement under which Valent BioSciences will be handling the sales of Actinovate AG biological fungicides developed by BioAg.

Valent U.S.A. (Valent) is a crop protection chemical manufacturer supplying products to the crop and professional markets. The company's U.S. headquarters is in Walnut Creek, CA.

HISTORY/OWNERSHIP STRUCTURE VALENT BIOSCIENCES

Valent BioSciences (VBC) was created in 2000 when Sumitomo Chemical Company purchased the agricultural products business of Abbott Laboratories. VBC's predecessor started the development of plant growth regulators in 1957, and today VBC has the most extensive portfolio of biorational products in the world.

VBC's parent company, Sumitomo Chemical Company (SCC), has 2016 global corporate revenues of close to \$17.7 billion.

Sumitomo Chemical's business dates back to 1913, when the company sought to solve the problem of pollution from copper smelting operations, by producing useful fertilizers from the emissions.

AGREEMENTS, JOINT VENTURES, ETC.

VBC enters into a long-term strategic alliance with Biomar Microbial Technologies under which the two companies will collaborate on the development of unique biorational products for the global agriculture, public health, and forestry markets. Biomar is a privately-held company based in Leon, Spain, dedicated to the discovery of microorganisms and their fermentation products for commercial applications. Biomar owns a diverse, proprietary library of more than 66,000 microbial strains isolated from marine samples collected from around the world. Under the expanded collaboration, Biomar will source and screen novel leads from its library, while VBC provides global R&D, regulatory and commercialization resources, leveraging its network of global distribution partners.

In 2013, MGK, an affiliate of Sumitomo Chemical Co., acquires the Environmental Science Division (ESD) of Valent BioSciences Corporation (VBC). The ESD division includes products targeting the professional non-crop markets; VBC will maintain its products and focus on the agricultural crop sectors. As of April 2015, Valent U.S.A. Corporation became the exclusive provider of the MGK crop protection line of insect control products within the United States. As prescribed in an agreement announced in October, Valent is now managing the marketing and sales of insect control products from Minneapolis-based MGK such as PyGanic, Azera, Veteran D, Tersusâ and EverGreen 60-6.

In 2016, Valent BioSciences Corporation (VBC) announced it has reached an agreement with The BioAg Alliance to distribute certain Actinovate Biological Fungicide products. Through the agreement, Actinovate AG brand sales for the United States will be handled through Valent U.S.A. Corporation and for Canada by Valent Canada, Inc. Actinovate AG is a broad spectrum biofungicide product for management of common foliar and soilborne diseases found on outdoor crops and in greenhouses, nurseries, and turf.

Valent completes the fifth year of its Biorational Business Unit in 2016. The business unit is focused on sales, support, and further development of biopesticide products. Biorational business has developed to capture growing sales within the biopesticide market. The unit operates separately from Valent BioSciences, of which Valent is an exclusive marketer in North America.

ACQUISITIONS

No acquisitions took place during the 2016 year.

VBC acquires Pace International in early 2013 for \$65 million. Pace International is a global leader in the postharvest segment of commercial agriculture with operations in the United States, Mexico, and South America. Previously, VBC owned 25% of the company.

R&D

VBC's Research Center is located in Long Grove, IL, and features greenhouses, walk-in growth chambers, advanced chemistry equipment such as automated flash chromatography, microwave reactors, HPLC, NMR, spray chamber/hood, and LIMS. The company states the capabilities of this facility enable its laboratory researchers and global field R&D teams to identify the best new products for field evaluation and commercial development.

The company states the scope of its R&D offerings and development activities include:

- Plant extracts
- Microbials
- Biochemical metabolites

MARKETING AND SALES

VBC's marketing and sales process includes identifying new uses for biorational technologies and successfully developing, registering, and launching products based on those innovations.

The company's business development partners typically include:

- Owners of new technology
- Start-ups
- Small companies in need of development and/or distribution partners
- Universities (tech transfer offices)
- Owners of commercial products (potential marketing partners, licensors for potential mixture products)
- Regional companies in need of distribution partners for specific territories
- Multinationals looking to leverage specific assets via a focused partner
- Owners of companies considering divestment
- Advisors to such companies

In 2017, Monsanto Company (NYSE: MON) and Valent U.S.A. LLC, announced an expanded partnership in the 2018 Roundup Ready PLUS Crop Management Solutions platform. Several key changes provide soybean, corn and cotton growers with the most effective solutions to be more productive. Valent will offer Valor and Fierce brands as the exclusive preemergence PPO residual herbicides in the program.

U.S. SALES

Table 125: Valent Product Group Sales Summary in the United States by Crop Markets, 2015 and 2016

Product group	\$ Million		Change	Change, %	% Of total
	2015	2016			
Herbicides	280	300	20	7.1	71.3
Insecticides	47	48	1	2.1	11.4
Fungicides	15	18	3	20	4.2
Plant growth regulators	19	29	10	52.6	6.9
Seed treatment	25	26	1	4.0	6.2
Total	386	421	35	9.1	100.0

Valents sales reflect that of Valent BioSciences, MGK, and the actinovate brand it markets for the Agbio Alliance.

VBC sales include both crop and noncrop markets. The crop markets include cotton, potatoes, nursery/greenhouse, and fruits. The professional markets include mosquito and forestry.

VBC biopesticide sales consist totally of insecticides. The company has a successful line of plant growth regulators, which are not considered biopesticides for purposes of this report, and are not included in the sales data.

VBC biopesticides sales total \$89.9 million in 2016.

PRODUCT LINE ANALYSIS

Table 126: Valent Biopesticide Product Sales in the United States, End-user Level, 2016

Major brand	Active ingredient	\$ Million	Target market(s)
Dipel DF	<i>Bacillus thuringiensis</i> ABTS-351	4.8	Fruit and vegetables, cotton
Vectolex	<i>Bt sphaericus</i>	1.1	Mosquito control
Xentari	<i>Bacillus thuringiensis aizawai</i> ABTS-1857	2.0	Fruit and vegetables, turf
Vectomax Vectolux	<i>Bt Israelensis + Bt sphaericus</i>	2.1	Mosquito control
Ditera	<i>Myrothecium verrucaria</i> strain AARC-0255	1.2	Fruit and vegetables
Aquabac, Vectobac, Gnatrol	<i>Bacillus thuringiensis israelensis</i>	12.4	Mosquito control, fruit and vegetables (minor)
Azera	Azadirachtin	2.0	Fruits and vegetables
VectoMax, Potatoe shield, Raven	<i>Bacillus thuringiensis tenebrionis</i>	6.0	Fruit and vegetables including potatoes
Mycoapply	Mycorrhizae	1.1	Fruits and vegetables
ProGib. Promalin, Provide, Maxcell	Giberillic acid	4.0	Fruits and vegetables
Retain	Aviglycine	18.0	Fruits
Pyganic, Evergreen, Pyrell	Pyrethrins	11.0	Pest Control, Mosquitoes, Fruits and vegetables
Actinovate	<i>Streptomyces lydicus</i>	12.3	Turf, Greenhouse, Nursery,
Other		11.9	Fruits, Vegetables, Pest control
Total		89.9	

STRATEGIC OUTLOOK TO 2021

The company's basic policy within its corporate business plan includes:

- Aggressively pursuing strategic investments to expand business
- Strengthening high-profitability businesses
- Contributing to enhancing food security.
- Improving public health and hygiene and the environment

Valent currently ranks number two in terms of sales within the U.S. biopesticide market, representing a 13% share of the market. The addition of MGK's pyrethrin and the actinovate products strengthens its position.

Valent is well-positioned to capture any growth opportunities available within the U.S. biopesticide market. The company is expected to add additional products under its Valent U.S.A. marketing portfolio within the next five years.

WOODSTREAM CORP.

OVERVIEW

Woodstream Corp. is headquartered in Lititz, PA, where it manufactures and markets a broad portfolio of consumer and professional pest control, pet care and garden care products.

In June 2003, Woodstream was acquired by private equity firm Brockway Moran & Partners in a partnership with its management. Prior to this acquisition, Woodstream was an independent, privately-held company that resulted from a management buyout in late 1999.

The 2003 deal transferred ownership of Woodstream from the Ekco Group Inc., a supplier of kitchen, bake ware, and house ware items based in Nashua, NH, to a group of Woodstream executives.

In 2000 and 2001, respectively, Woodstream bought out two well-recognized bird feeder manufacturers, Hyde and K Feeder, as well as the DeerOff line of products. In 2005, the company acquired Fi-Shock, a manufacturer of electric and high-tensile fencing products that are used to contain and/or exclude livestock, pets and wildlife, including the Bird Repel system.

In April 2007, Woodstream acquired the Mosquito Magnet line of products from American Biophysics Corp; the \$6 million deal includes the Defender, Liberty and Liberty Plus models and the Net and Attractant consumables associated with these products.

In April 2007, Woodstream acquired the Mosquito Magnet line of products from American Biophysics Corp; the \$6 million deal includes the Defender, Liberty and Liberty Plus models and the Net and Attractant consumables associated with these products.

In 2007, Woodstream acquired Dr. T's Nature Products, a manufacturer of 16 unique, environmental friendly pest repellents for both the consumer and commercial markets.

In April 2012, Woodstream Corporation completed the acquisition of Senoret Group, Inc. and its related entities and brands TERRO and Sweeney's.

In 2015 Vestar Capital Partners, Brockway Moran & Partners and CHS Capital announced that Vestar has signed a definitive agreement to acquire Woodstream, from Brockway Moran and CHS Capital. Terms were not disclosed. The transaction is expected to close in the second quarter of 2015.

SALES AND PROFITS

Woodstream's products are sold at more than 100,000 retail locations throughout the United States, Canada and other international markets, including channels such as Ace, Agway, Home Depot, Kmart, Lowes, Menards, Rite Aid, and True Value. International sales represent approximately 10% of Woodstream's total sales, with the strongest sales in Canada and Europe. Woodstream also offers professional products, which represent only about 10% of its total sales. All products are sold under the company's own brand names. While Woodstream releases limited financial information, total sales in 2016 are estimated to be \$300 million.

CONSUMER PESTICIDES AND FERTILIZERS

Woodstream is the world leader in least toxic pest control, manufacturing, and marketing two major product lines, Victor and Havahart, in addition to newly acquired brands.

The Victor line represents patented, low-toxicity solutions composed of mint oil, fatty acid soaps, and pheromone attractants that focuses on fly, moth, roach, and ant control.

Fly control products include bottle traps, sticky traps, a fly scoop, fly lights, and an aerosol.

In 2005, the company launched the Victor Fly Magnet and Victor Yellowjacket Magnet bag traps, offering easy disposal of flies and yellowjackets without a mess.

Moth control products include a pantry trap and clothes traps containing a pheromone lure.

Roach control products include traps and bait stations, crack and crevice powders, Concern Citrus Home Pest Control Spray, Concern Diatomaceous Earth Crawling Insect Killer and Victor Poison-Free. The line also includes a mouse snap trap—the original core Woodstream product—as well as a novel electronic mouse trap that uses smart electronics for a fast, humane, safe, clean catch with easy disposal.

Ant control products include baits and powders, Safer Home Patrol Insect Killer, and an aerosol.

Woodstream Corporation has approximately 60 organic products in its line. These products come under the Safer, Concer, Terro, Ringer, and Havahart brand names.

In 2009, Woodstream Corporation's Safer Brand released ready-to-spray organic pest control concentrates.

Safer Brand Bug Patrol, Mosquito & Tick Killer, and Grub Killer are used in ready-to-spray concentrate formulations that connect to a garden hose for simple organic pest control.

The organic insecticides provide quick, consistent coverage throughout a garden or yard, without the hand fatigue associated with spray bottles.

Terro is a boric acid-based ant bait.

Table 127: Woodstream's Sales of Pesticides and Related Products to Consumer Markets in the United States, 2016

Product category	\$ Million	% Of total
VICTOR SAFE		
Rodent control	45	18.0
Indoor insecticide	19	7.6
Fertilizers	20	8.0
Outdoor insecticides	11	4.4
Fungicides	11	4.4
All other-a	25	10.0
Total	131	52.4
TERRO	23	9.2
SWEENEY'S	7	2.8
HAVAHAART	60	24.0
MOSQUITO MAGNET	7	2.8
DR. T.'S	5	2.0
ALL OTHER-b	18	7.2
TOTAL-c	250	100.0

a- Includes insect repellents and traps, among other products.

b- Includes international and professional sales as well as sales of fencing and bird feeders.

c- Totals may not add due to rounding.

Table 128: Woodstream's Sales of Biopesticides to Consumer Markets in the United States, End-user Level, 2016

Active	Brand(s)	\$ Million
Sodium tetraborate decahydrate	Terro Ant Baits	8.0
Corn gluten	Concern Weed Prevention Plus	4.0
Pyrethrin + fatty acids	Safer Mosquito and Tick, Safer Flying Insect, Safer Ant & Roach	4.0
Lemon grass, Mint, garlic oil	Dr. T's repellants	3.0
Diatomaceous earth	Safer Bed Bug, Ant, Crawling Insect	3.0
Neem oil	Safer Brand Grub Killer	3.0
Total		25.0

MARKETING POLICIES

Woodstream's products are marketed through distributors to leading retailers in the United States, as well as online through the company's websites. New product launches have been low for the last couple of years, and the company is ensuring that they take a reasonable amount of risk in order to sustain in the market.

FACILITIES

Woodstream operates warehousing and administration facilities in Lititz, PA, with satellite warehouse operations in Missouri and California. Manufacturing for Woodstream products is done in Lititz, PA, and in Scarborough, Toronto, Canada. Woodstream employs approximately 235 persons.

STRATEGIC OUTLOOK TO 2021

Over the next five years, Woodstream will continue to exceed the average rate of growth of the market, as the company maintains a brisk pace of acquisition activity and enjoys strong sales of its established brands. Woodstream's low toxicity Victor line will grow by an estimated 6% per year on strong consumer appeal of low-toxicity lawn and garden products. Gains are being driven by consumer concerns over household usage of poisons. Woodstream will particularly benefit from this trend, with an inexpensive, environmental friendly product sold by more than 100,000 U.S. retailers.

FUTUREVIEW OUTLOOK AND FORECAST FOR BIOPESTICIDES, 2017 TO 2022

Biopesticides occupy a small but growing niche in the crop protection universe. The family of products currently on the market and reported here account for \$784.0 million in sales at end-user values, or about 5% of the industry. However, societal forces and the resulting response by the industry to broaden product lines and improve performance are resulting in growth opportunities.

At the end of each section in this report, Kline discusses growth opportunities for biopesticides. Those opportunities are summarized here as background for the forecasts.

OPPORTUNITIES FOR BIOPESTICIDES FOR USE AS SEED TREATMENTS IN FIELD CROPS

Interest in reducing chemical use provides a definite market opportunity providing performance is comparable.

While there is still insufficient understanding of all the complex and delicate interactions occurring in the soil, it is more likely that a microbial product will be less likely to interfere with the mycorrhizal root interaction.

Several soil diseases remain difficult to control so that any product able to colonize roots and protect them would be highly desirable. Take-all in wheat and Sudden Death Syndrome in soybeans are good examples of this.

OPPORTUNITIES FOR BIOPESTICIDES IN FRUIT

The strong interest in IPM for fruit production creates opportunities for products for insect and pathogen control that are specific in action and do not affect beneficial species.

Products that can be applied close to harvest and that have minimal re-entry intervals will provide flexibility to fruit producers.

The list of fruit industry needs was developed by those extension and research staff interviewed.

Table 129: Priority Target for Biopesticides on Fruit, 2016

Priority	Target
1	Citrus greening
2	Spotted Wing Drosophila—all fruit
3	Marmorated Stink Bugs—all fruit
4	Brown Rot, Blossom Blight, and Fruit Rot—stone fruit
5	Mosquitos

OPPORTUNITIES FOR BIOPESTICIDES IN VEGETABLES

The role of consumer concerns will further encourage growers, shippers, and supermarket chains to promote chemical-free and sustainable methods used to grow the fresh produce and also processed vegetables. Biopesticides will be able to play a valuable role, if not during the whole growth cycle, at least at key points, such as before harvesting.

For vegetable producers involved in or considering export markets, biopesticides can be valuable in reducing if not avoiding residues, so that there will be no problem in meeting requirements of importing countries.

Several food processors and supermarket chains have policies that indicate their definite move to products that are produced more sustainably. Food and produce companies will use more labels indicating that their products are “natural,” or “locally produced,” and “sustainable,” with efforts to ensure that their producers are practicing IPM and minimizing the use of chemicals.

Conventional products do not provide effective control of all the insects, and pathogens and nematodes, in particular, such as the bacteria black rot of crucifers (*Xanthomonas campestris* pv. *campestris*), tomato bacterial speck and spot (*Pseudomonas syringae* pv. *tomato*), and soil-borne pathogens such as *Phytophthora capsici* and *Verticillium* spp.

In organic production, there are many common diseases, such as Botryis, leaf mold, and powdery mildew in high tunnel tomatoes, and many other common diseases in standard production. Viral diseases are also not addressed with the current armory of pesticide products, and producers would like to have a product that would control aflatoxin.

A recent listing, produced at the IR-4 Biopesticides Workshop in September 2014, of the need for control measures in organic production that can control certain diseases and insects, in order of priority were:

- Bacterial diseases of fruiting vegetables—both field and greenhouse
- Downy mildew in basil—field and greenhouse
- Whitefly, aphids and psyllids in greenhouse tomatoes
- Mites, thrips, aphids and whiteflies in vegetables
- Thrips in all crops, *Phytophthora capsici* in field vegetables

OPPORTUNITIES FOR BIOPESTICIDES IN ORGANIC PRODUCTION

Since certified organic producers can only use OMRI certified products, and any biopesticides with enhanced performance will be welcomed by organic producers. Quality Assurance International considers that there will be stricter regulation of organic production and that organic will be linked with food safety and “other food integrity programs.” International standards will also be established. Growers will have to use products that meet the new standards and will not wish to risk using conventional products.

Some organizations are forecasting that fruit and vegetables will continue to dominate the organic food category so that there will continue to be good opportunities for effective products that can be used.

A listing of priority targets was voted at the September 2014 IR-4 Biopesticide Workshop as follows:

- Fireblight in organic apples
- Weed control in all organic crops
- Mummy berry (*Monilinia vaccini-corymbosa*), Anthracnose, *Alternaria* in blueberries
- Late blight in tomatoes
- Downy mildew in pumpkin and squash

Most if not all of the opportunities listed under the other crop/market segments also apply to this specific organic segment.

There is undoubtedly strong interest in biopesticides that perform well. There is growth in organic production; even though the market is small compared to the conventional market, sales can provide a valuable base.

OPPORTUNITIES FOR BIOPESTICIDES IN NURSERY/GREENHOUSE PRODUCTION

Biopesticides fit well with the insect and disease management strategies used by growers. That fact provided reasons for likely growth of biopesticides in greenhouses and nurseries, including:

- Control resistance diseases
- Protect predatory species
- Shorten re-entry interval to increase labor efficiency
- Utilize the multiple modes of action featured by biopesticides to fend off resistance to chemicals
- Use preventative treatments take advantage of that biopesticide feature
- Help replace the function of soil fumigation by using biological disease control

PROMISING AREAS FOR GROWTH IN POTATOES

There are four potential market segments for disease control in potatoes:

- Pre-planting—Replace the disease and nematode control provided by fumigants
- Seed-piece treatment in furrow
- Control of foliage disease
- Tuber storage

Pre-planting

It seems likely if not inevitable that current fumigants will no longer be registered without draconian label restrictions. Fumigants have been used in potatoes to control nematodes, soil pathogens, and Potato Early Dying complex, which are caused by the interaction between *Pratylenchus* spp. and *Verticillium dahlia*. The biofumigant Dominus has been registered with a broad label, and as it is not an actual organism, it may have a greater chance of more consistent performance as it is not so dependent on temperature, moisture conditions, etc.

There is also potential for bionematicides to replace fumigants and products such as Vydate oxamyl.

The challenges for any microbial biopesticide are the need for conditions favoring their existence and replication. Certainly, under conditions in Idaho soil temperature and moisture content can vary hugely. However, this is certainly a potential market for an effective product. Ideally, the product should control the target organisms and not control natural organisms and predators.

Seed piece treatment

So far, trials have shown that in-furrow treatment appears to have been more effective than seed piece application. The concept of a microbial application that allows the bacteria to develop with the crop is attractive, and protects the roots and developing new tubers through harvesting and even storage.

A major product that has been widely used in potatoes for seed piece treatment is Maxim fludioxonil, but pathotypes of *Fusarium* have developed levels of resistance to the fungicide. Recently, registered conventional fungicides are now available and labeled for *Fusarium*, but collaborative research is showing that the biofungicides, T-22 *Trichoderma harzianum* and Serenade Plus *Bacillus subtilis* can be effective for the control of Dry or Sprout rot and seed piece decay caused by *Fusarium sambucinum* when applied to healthy seed. These have shown promise in the control of seed and soil-borne diseases, such as late blight, black scurf, dry rot, and silver scurf.

T. harzianum can grow and colonize new stems, stolons, and roots of the developing potato plant throughout the growing season and so maintain its efficacy. This not only provides seed piece protection, particularly from in-furrow application, but enables the new tubers to be protected from infection and so enter storage without such high levels of infection.

This concept of life history protection is being investigated in research at several research centers and being funded by the USDA. It is a valuable project that is investigating how the strategic control of pathogens can be achieved by control with biopesticides at critical periods in the life cycle.

Foliar disease control

Biofungicides can provide control of late blight but only preventively. Fantastic results can be obtained, but under different circumstances, results may be poor due to disease pressure and environmental conditions. There is a much narrower window for biofungicides which do not work so well under high stress and disease pressure. It should be possible to replace two conventional sprays or alternate conventional and biofungicides. Early blight disease only affects plants when they begin to senesce, and so provides only a narrow window for control due to the need to apply early. There is reduced potential for controlling this disease.

Insect control

Resistance to neonicotinoids in Colorado potato beetle has developed, so there is potential for a bioinsecticide to alternate with existing and new synthetic insecticides in a program to delay resistance and maintain existing chemicals. Grandevo *Chromobacterium subtsugae* PRAA4-1 provides broad spectrum control of chewing and sucking insects.

Tuber storage

This is a very challenging area, as the food industry is extremely concerned about chemical residues on tubers being stored for consumption. Only one product, Syngenta's Stadium, has been registered. An additional challenge is the fact that any water sprayed on to the tubers may provide ideal conditions for pathogens to spread. A biofungicide might have the ideal properties to provide good control, but will still need to be applied in sufficient volume of water to obtain good coverage.

OPPORTUNITIES FOR BIOLOGICAL MOSQUITO PRODUCTS

The need for mosquito control biopesticides was the top priority listed as a result of the IR-4 Workshop held at Rutgers in September 2014.

While resistance does not seem to be a potential concern for the current *Bt israelensis* and *B. sphaericus* products, there would be potential for a highly specific larvicide product that could last longer, and yet was totally safe in water to aquatic and other non-target organisms, including wildlife and human beings.

Kline believes that there will be greater use of larvicides, particularly if the products demonstrate enhanced longevity and high levels of efficacy against all common mosquitoes: Anopheles, Culex, and Aedes.

The challenge with adulticides is the low cost of current products in a rather limited market. However, the ability to claim EPA registered biological will be a valuable marketing asset in this highly sensitive market.

OPPORTUNITIES FOR BIOPESTICIDES FOR USE ON TURF GRASS

Pressure is building to reduce the use of chemicals or synthetics on turf grass. This is greatest in public areas, sports turf, and golf courses, where use has been high due to the high-quality turf required. This pressure is particularly high in areas with groundwater concerns, as on Long Island.

There was the understanding, at least amongst respondents, that current fungicide biopesticides, in particular, cannot be used on their own. As they are not curative, they must be used preventively in programs, particularly when high-quality turf is required. There seemed to be some agreement that combinations with conventional fungicides products were better than alternating biopesticides and conventional fungicides.

Local resistant pathogens may provide openings for biopesticides or to incorporate a biopesticide into the current program to delay pathogen resistance.

Insecticide opportunities also exist to reduce the use of chemicals and also due to actual insect resistance or to delay resistance development.

Finally, there is no effective biological herbicide that can be used economically to control weeds. Such a product should ideally control a range of weeds, but dandelions are ubiquitous so would still be of interest.

Biopesticides for nematode control should find a valuable niche in this small but valuable market and satisfy the need for safe and effective products. Precisely timed preventive treatments using IPM could also reduce the total number of applications required, which would be desirable to turf managers if not the suppliers. Environmental and operator safety are also important for golf course owners.

There is strong interest from golf courses and public space managers in herbicides considered to be biopesticides. Several are under development, but this report could find no examples of their availability as OTC product.

OPPORTUNITIES FOR BIOPESTICIDES IN FORESTRY

The U.S. Forest Service assessment of forests and predictions of losses in the future has estimated that there are 71.7 million acres of forest at risk in the coterminous United States and a further 9.5 million acres in Alaska. This is divided between Forest Service administered forests, other federal land and all other forest areas.

The Forest Service reports that the major problems in the continental United States are root diseases, bark beetles, and oak decline.

The reality is that the use of pesticides, including biopesticides, is almost non-existent. It is difficult to see the situation changing in the next 5 to 10 years. Federal and state forests have become symbols of the natural environment, and as such, are not supposed to be polluted by chemicals. Environmentally acceptable products will be challenged to provide the persistence and specificity required to warrant development and marketing. Cost will also be an obvious deterrent to widespread use.

Ongoing forest projects indicate current U.S. Forest Research Service research and development efforts underway including:

- Optimizing Gypchek and TM-biocontrol-1 for operational use
- Maximizing efficacy of Spinosad and Bt toxins for landscape treatment of Emerald Ash Borer
- Maximizing efficacy of entomopathogens for landscape treatment of hemlock woolly adelgid.
- Developing herbicides for invasive plants
- Finding ways to control or deal with Mountain pine beetles in various pine species which “may be the largest forest insect blight”

OPPORTUNITIES FOR BIOPESTICIDES IN CONSUMER OTC MARKETS

The requirements for consumer OTC products are even more stringent than for products used in commercial agriculture. However, there is need for products that provide contact and residual control, but are completely safe to applicators, children, and pets, and safe if they get into stormwater or groundwater.

The following opportunities are mentioned by interview respondents as potential markets for biologically-based pesticides:

- Termites
- Bed bugs
- Selective herbicide for use in turf grass
- Contact herbicide

LIKELY CASE FORECAST

A likely case forecast is based on three elements: inflation, natural market growth, and chemical manufacturers’ ability to push biologicals through the channels to users. The latter element is a newer feature for biopesticides, as major companies are seeking to exploit the societal and regulatory environment that favors safer products.

Kline is allowing for a 2% annual inflation rate in pricing in the likely case. The natural market growth varies from a high of 5.0% for field crops to a low of 1.0% for certain non-crop markets, such as mosquito control and forestry.

The manufacturer push impact on the market is significant. It ranges from a high of 4% per year for field crops and consumer markets, to a low of no impact in some mature biological markets in non-crop, such as mosquito control and forestry.

Kline believes that field crops and consumer segments offer the best opportunity for manufacturer push to succeed, mainly because of the relative immaturity of the segments, the receptivity to alternatives if performance can be documented, and the ability of manufacturers to influence behavior.

The low rates for forestry and mosquito control is influenced by the need for public funding for both, and the general resistance to applying insecticides of any type to our forests. The high rate for field crops is based on the potential for expanding biological seed treatments further into soybeans and cotton.

For fruit and vegetable crops, as new products with improved performance are introduced, the advantages offered to growers in pest control and to supply chains in safe produce will motivate increasing use of biologicals. However, these products are more mature in fruit and vegetable sectors, so the growth opportunity is perceived to be less attractive than in field crops.

Table 130: Assumptions for a Likely Case Biopesticide Forecast in the United States, 2017 to 2022

Segment	Inflation	Growth	CAGR, %	
			Mfg. push	Total
FIELD CROPS	2.0	5.0	2.0	9.0
FRUIT CROPS	2.0	3.0	2.0	7.0
VEGETABLE CROPS	2.0	3.0	2.0	7.0
SPECIALTY				
Greenhouse/nursery	2.0	3.0	1.0	6.0
NON-CROP				
Mosquito control	2.0	1.0	-	3.0
Turf	2.0	3.0	2.0	7.0
Forestry	2.0	1.0	-	3.0
Pest control	2.0	1.0	-	3.0
Total	2.0	1.5	0.5	4.0
CONSUMER	2.0	5.0	4.0	11.0

In a likely case forecast for the period 2017 through 2022, sales are projected to grow from \$812.2 million to nearly \$1,262.1 million, up at a CAGR 8.3%.

Table 131: Likely Case Forecast for Biopesticides in the United States, 2017 to 2022

Segment	\$ Million					
	2017	2018	2019	2020	2021	2022
FIELD CROPS	261.5	285.1	310.7	338.6	369.1	402.3
FRUIT CROPS	111.3	119.1	127.4	136.3	145.9	156.1
VEGETABLE CROPS	97.3	104.1	111.4	119.2	127.5	136.4
SPECIALTY						
Greenhouse/nursery	41.6	44.0	46.7	49.5	52.5	55.6
NON-CROP	85.9	89.3	92.9	96.6	100.5	104.5
CONSUMER	214.6	268.2	297.7	330.5	366.8	407.2
TOTAL	812.2	909.8	986.8	1,070.7	1,162.2	1,262.1

OPTIMISTIC CASE FORECAST

The optimistic case forecast projects inflationary price increases of 2.0% annually and higher growth rates for all segments, ranging from a total of 7.0% on the low side for mosquito control and forestry to a high of 15.0% annually for field crops. The other segments show growth rates between 8.0% and 14.0%.

Table 132: Optimistic Case Biopesticide Forecast Assumptions in the United States, 2014 to 2019

Segment	Inflation	Growth	CAGR, %	
			Mfg push	Total
FIELD CROPS	2.0	9.0	4.0	15.0
FRUIT CROPS	2.0	6.0	2.0	10.0
VEGETABLE CROPS	2.0	6.0	2.0	10.0
SPECIALTY				
Potatoes	2.0	5.0	1.0	8.0
Greenhouse/nursery	2.0	5.0	1.0	8.0
Total	2.0	1.4	1.0	8.0
NON-CROP				
Mosquito control	2.0	5.0	-	7.0
Turf	2.0	9.0	2.0	13.0
Forestry	2.0	6.0	-	8.0
Pest control	2.0	5.0	-	7.0
Total	2.0	0.9	-	8.8
CONSUMER	2.0	8.0	4.0	14.0

The optimistic case forecast indicates growth from \$870.5 million to \$1,577.2 million in 2022, a CAGR of 12.2%.

Table 133: Optimistic Case Forecast for Biopesticide Sales in the United States, 2017 to 2022

Segment	\$ Million					
	2017	2018	2019	2020	2021	2022
FIELD CROPS	275.9	317.3	364.9	419.6	482.5	554.9
FRUIT CROPS	114.4	125.8	138.4	152.3	167.5	184.3
VEGETABLE CROPS	99.9	109.9	121.0	133.0	146.4	161.0
SPECIALTY						
Greenhouse/nursery	42.3	45.7	49.4	53.3	57.6	62.2
NON-CROP						
Total	89.8	97.8	106.4	115.7	125.9	137.0
CONSUMER	248.2	282.9	322.5	367.7	419.2	477.8
TOTAL	870.5	979.4	1,102.6	1,241.6	1,399.1	1,577.2

PESSIMISTIC CASE FORECAST

The pessimistic case forecast for U.S. biopesticides reflects projected growth for the total market of 2.4%, with individual segments varying from 1.0% to 3.0% annually. Sales are projected to increase from \$481.2 million to \$550.1 million. The pessimistic case assumes low growth and low ability to pass along price increases in a market that is not growing as expected. This will be due to slower than anticipated introductions of new and improved products, as well as slower acceptance by end users. Moreover, the manufacturer push referred to in the likely and optimistic cases is assumed to be relatively ineffective in changing behavior in the pessimistic case.

Table 134 Pessimistic Forecast Assumptions for Biopesticide Sales in the United States, 2017-2022

Segment	CAGR, %			
	Inflation	Growth	Mfg push	Total
FIELD CROPS	1.0	2.5	-	3.5
FRUIT CROPS	1.0	1.5	-	2.5
VEGETABLE CROPS	1.0	2.5	-	3.5
SPECIALTY				
Greenhouse/nursery	1.0	1.5	-	2.5
NON-CROP				
Total noncrop	1.0	0.9	-	1.9
CONSUMER	1.0	1.5	-	2.5

The market increases from \$796.0 million to \$918.1 million by 2022, a CAGR% of 2.7%, in the pessimistic case.

Table 135: Pessimistic Forecast For. Biopesticide Sales in the United States, 2017 to 2022

	\$ Million					
Segment	2017	2018	2019	2020	2021	2022
FIELD CROPS	248.0	256.9	266.0	275.3	284.9	294.9
FRUIT CROPS	106.6	109.3	112.0	114.8	117.7	121.0
VEGETABLE CROPS	94.0	97.4	100.8	104.3	108.0	111.7
SPECIALTY						
Greenhouse/nursery	40.2	41.2	42.2	43.3	44.3	45.5
NON-CROP						
Total	84.1	85.8	87.4	89.1	90.8	92.5
CONSUMER	223.1	228.7	234.4	240.3	246.3	252.5
TOTAL	796.0	819.3	842.8	867.1	892.0	918.1

Growth rates are spread between 2.7% on the low end and 12.2% on the high end. This range is far more bullish than most of Kline's forecast, but with such a large market already established for traditional chemicals, and such a strong societal push for less toxic alternatives, Kline estimates that these growth rates are attainable. It should be noted that these growth rates are lower than some others, but reflect a high degree of confidence in the potential growth in crop and consumer markets.

Table 136: Biopesticide Forecast Case Comparison in the United States, 2017-2022

	\$ Million						
Scenario	2017	2018	2019	2020	2021	2022	CAGR, %
Optimistic case	870.5	979.4	1,102.6	1,241.6	1,399.1	1,577.2	12.2
Likely case	812.2	909.8	986.8	1,070.7	1,162.2	1,262.1	8.3
Pessimistic case	796.5	819.3	842.8	867.1	892.0	918.1	2.7

Figure 2: U.S. Biopesticide Forecast Case Comparison, 2017 to 2022